superior name contains 12 units of its next inferior name; this system is therefore called the *duodecimal system* (from the Latin word for *twelve*). Our mode of counting money is a mixture of systems. We divide it into pounds, shillings, and pence, of which 12 pence make a shilling, and 20 shillings a pound. We write a number of pounds, shillings, and pence, thus, £2 : 5 : 11, where £ shows that 2 is pounds, and as shillings is the next lower name, and pence the next in succession to shillings, the meanings of the 5 and the 11 are obvious. This variation in the value of the units renders the calculation of sums of money more complex than those with abstract numbers. The same is likewise true of all our systems of weights and measures, as we will hereafter find.

14. The systems of arithmetical notation employed by the ancients, were exceedingly inconvenient and imperfect. They served laboriously to register a number that was not very great, but they could not afford the slightest aid in performing arithmetical computation. In the simple calculations which it was absolutely necessary to make, recourse was had to some sort of mechanical contrivance, of which the *Abacus* of the old Romans, and *Swan-pan* of the Chinese, are examples. To form a notion of such an instrument, it is only necessary to suppose a board with a number of lines drawn upon it, as represented in the figure, and that each pebble or counter placed on the space A denotes 1; each on the space B denotes 10; each on the space C denotes 100; and so on; so that, taking the ciphers for counters, the number represented by their disposition in the figure, will be 123142. With such an instrument, (considerably inferior, however,) the Romans made all their heavy calculations,* and noted the results by the letters of their alphabet. This method of writing numbers we have still retained for some purposes, as for marking the chapters of books, the year of the Christian era, hours on dial-plates, and so forth. The letters employed are I, V, X, L, C, D, M; the I to denote 1; the V, 5; the X, 10; the L, 50; the C, 100; the D, 500; and the M, 1000. IƆ has the same meaning as D, and CIƆ as M. These letters, when thus employed, are called *numerals*, and the principles upon which they are combined, so as to stand for intermediate and for higher numbers, are these:—

F	0
E	00
D	000
C	0
B	0000
A	00

The repetition of a letter denotes the repetition of the number it represents; thus, III denotes three ones, and XXX denotes three tens, and so on.

When a letter expressing a less number is placed *after* a greater, the values of the numerals are to be taken together. Thus, XI means ten and one, or eleven; LX means 50 and 10, or 60.

When a numeral of a less value is placed *before* one of greater, its value is to be deducted. Thus, IV means 5 *less* 1, or 4; XL means 50 *less* 10, or 40.

When Ɔ is annexed to IƆ, it increases the value of that character ten times. Thus, IƆƆ is 5000, and IƆƆƆ is 50,000. In like manner, CIƆ is increased in value ten times by prefixing C and annexing Ɔ. Thus, CCIƆƆ is 10,000, and CCCIƆƆƆ is 100,000.

Lastly, a line drawn *over* a numeral increases its value a thousand times. Thus, $\overline{X}$ stands for 10,000.

The following table exhibits these principles more fully:—

Units.	Tens.	Hundreds.	Thousands.
I 1	X 10	C....................100	M or CIƆ 1000
II............2	XX 20	CC....................200	MM or $\overline{II}$..............2000
III 3	XXX.....30	CCC..................300	MMM or $\overline{III}$ 3000
IIII or IV...4	XL 40	CCCC or CD.........400	MMMM or $\overline{IV}$.........4000
V..............5	L...........50	D or IƆ................500	IƆƆ or $\overline{V}$...............5000
VI 6	LX........60	DC or IƆC..........600	IƆƆM or $\overline{VI}$...........6000
VII 7	LXX 70	DCC or IƆCC.......700	IƆƆMM or $\overline{VII}$ 7000
VIII 8	LXXX...80	DCCC or IƆCCC...800	IƆƆMMM or $\overline{VIII}$...8000
IX.............9	XC........90	CM....................900	IƆƆMMMM or $\overline{IX}$...9000

* The word *calculation* is derived from *calculus*, a pebble, pebbles being originally used on the abacus. In process of luxury, *tali* or little dies made of ivory, were used instead of pebbles, and small silver coins instead of counters.

The following particular cases of combination may be observed:—

XVII for..............17	DCCXIX for.........719	$\overline{VII}$CC for 7,200
XXIV...................24	CDXC, or XD........490	$\overline{XXX}$XC...........30,090
XXXIX..................39	MDCCCXLI........1841	CCIƆƆXL..........10,040

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ANATOMY AND PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

There is *no subject* in which the people are so deeply interested as to know the structure and functions of their own bodies. And yet there is *nothing* of which they are in general so deplorably ignorant. In the pulpit they sometimes hear the exclamation, "that they are fearfully and wonderfully made," but it constitutes the sum and substance of their anatomical knowledge. How astonishing that mankind should exhibit so little curiosity to know themselves! Why do this apathy and ignorance prevail? It is because anatomy and physiology do *not* form an elementary branch of juvenile education. Juvenile teachers do *not* understand them, and therefore *cannot* impart them.

In consonance with the ignorance and practice of the old pedagogues of our ancestors, children are still compelled to waste too much of the best portion of their early lives in the useless study of guttural sounds, obsolete words, dead languages, Greek and Latin poetry, ecclesiastical dogmas, and abstruse catechisms; and this is boastingly misnamed a useful education. What a misnomer of knowledge! It is like gravely presenting an apprentice-boy a few childish toys to play with, instead of giving him useful tools and teaching him his trade. It is like teaching astrology instead of astronomy—alchemy instead of chemistry—metaphysics instead of phrenology—magic instead of science—charlatanerie instead of surgery—and superstition instead of wisdom. It is making mankind move forever in one limited circle, and beyond it everything seems dark and mysterious. It is teaching them to quake like children at a thunder-storm, instead of disclosing the laws of electric phenomena—pointing the iron rod to the clouds, and directing the lightning to pass harmlessly into the earth. It is glorious for mankind that some philosophers have boldly overleapt the prescribed limits of their scholastic education, fearlessly examined the structure and laws of matter, and honestly explained them to the people. Galileo, Franklin, and Sir Isaac Newton, have burst the gates of superstition, opened to us the lucid windows of heaven, and we now behold the celestial phenomena with rational delight, and understand them.

Harvey discovered the circulation of the blood only by examining the human body, and studying its laws—not by bowing down with reverence to the dogmas of schools—and he banished from anatomical cloisters the hypothetic jargon of licensed empiricism, and in despite of medical anathemas and persecution, gloriously triumphed. Jenner unfolded the safety and utility of *vaccine inoculation*, and preserved the lives of millions of human beings, notwithstanding the outrages and selfishness of all the medical faculties of Europe combined to destroy it. Hundreds of anatomists, in almost every kingdom, have secretly dissected dead bodies, and disclosed their structure and functions to their pupils, although the arm of popular violence was often raised to annihilate them. In our own land, Sir Charles Bell has reaped immortal fame by his anatomical researches, and has explained the mechanism and laws of the animal machine to chirurgeons with as much accuracy and simplicity, as Watt has unfolded to engineers his extraordinary, yet simple, hydraulic engine.

In one short essay, very little knowledge can be conveyed of the structure and functions of the human body; it is only by commencing at the beginning of the subject, and proceeding with a regular series of articles in succeeding monthly journals to its termination, that we can learn to comprehend ourselves; and, after minute investigation, the skilful arrangement, symmetry, uses, and beauty of the animal machine will be rationally per-

ceived and appreciated. We admire the steam-engine—it is worthy of admiration—it is one of the greatest and most useful inventions of *man;* but *man* is a machine, that for mechanical arrangement and accurate adaptation, as far surpasses *it,* as a natural plant excels an artificial flower. There is nothing like *man* in organic matter. He bears *upon him,* and *within him,* the impression of his almighty Creator. No man can be an atheist who understands the structure and laws of his own body. From conception till death, we are endowed with a mysterious vitality; and when our mortal destiny is finished, life extinguishes, and our bodies resolve into the elements that compose them. This is an organic law of nature, inexplicable, immutable, irrevocable; and no animal is exempted from its fatality.

The human body is composed of parts; *each part* constitutes a *separate* economy, depending on the *whole,* and the *whole* is sustained by its *parts.* Internally there is a strong *framework* of bones, and on *these* the superstructure is built: over the bones is laid a thick bed of muscular flesh, in regular thin layers, composed of long slender fibres, each layer acting like a pulley, raising and depressing the bones at the will of the individual. To the extremity of each of the deep-seated muscles (over the bones,) a piece of strong white tendinous cord is attached, and inserted into the bone, by which it is moved and motion is performed; the joints are mechanically constructed, and nicely adapted to each other, and attached by ligamentous bands that bind them together and prevent dislocation. In the bones, in the muscular flesh, and in every part of the body, blood-vessels, composed of arteries and veins, ramify in every direction, from the thickness of a child's wrist, to an almost imperceptible thread. The arteries convey the oxygenized blood to every part of the body, to repair its waste, and cause it to grow. Tho veins return the carbonized blood back to the heart, unfit for nutrition, to be re-oxygenized by the inhalation of atmospheric air in the lungs, and deprived (by expiration,) of the carbon and hydrogen that rendered it destructive to animal life.

In the abdomen (or belly,) we have the stomach, bowels, liver, spleen, pancreas, and kidneys, each and all performing their separate work, with silence, order, and harmony. The stomach receives the masticated food, and, by its gastric juice, digests it. It requires about four hours to complete healthy digestion. The liver pours its bile into the duodenum (or first gut), assists digestion, separates the nutritious from the excrementitious aliment, and aids the expulsion of the latter. In the upper region of the bowels, the lacteals (little absorbent vessels,) suck the nourishing part of the food, and send it, by the mesenteric glands, into the receptacle of the chyle; it then passes into the chyle-duct, (transformed into a milky fluid,) and ascends, by muscular action, contrary to the laws of gravity, until beneath the left-shoulder it oozes into the left sub-clavian vein, and mingles with the blood.

In the chest we have the lungs, composed of delicate cells and blood-vessels, receiving and expelling the respired air. The circulating fluid passes from the heart into the lungs, and is there exposed to the action of the air we breathe. It parts with the carbonic acid, hydrogen, and watery vapour which it imbibed in circulation, and absorbs oxygen; changes from a dark-purple to a bright scarlet-red, returns to the heart, and is sent, by the simultaneous action of the arteries, into every part of the body, to nourish and repair it. This extraordinary process never ceases till we die. In every age and clime it proceeds with the same regularity, without our consciousness and will. There are about twenty-five pounds of blood in a full-grown man.

In the hollow of the skull we have the brain—the most mysterious organ in nature. It is divided into two hemispheres, several lobes, and enclosed in three membranes. We have two distinct brains—the cerebrum before, and the cerebellum behind: the spinal cord is a prolongation of the brain, enclosed in twenty-four bones, joined together by intermediate cartilages, that render it flexible, and by the nicest mechanism, prevents spinal compression. From the brain and spinal cord numerous nerves extend in every direction, from the thickness of the little finger, to the finest gossamer-thread; giving life, sensation, and motion, to every part of the body. The brain seems to be an animo-galvanic apparatus, in which the vital principle is generated, and the nerves are vital conductors. The nerves of the senses communicate between tho mind and the external world through the medium of the brain. The spinal cord derives its function directly from the brain, and gives motion and sensation (by two sets of nerves) to the parts supplied. The heart and arteries pulsate by nervous power, received from the brain, and are stimulated by the circulating blood. We move our bodies by nervous energy derived from the spinal cord and the brain. We see, hear, taste, feel, smell, eat, drink, digest, grow, and renew, by nervous influence, that has its *origin* in the brain. The mind resides in the brain; we cannot live, think, reason, judge, nor do any thing vital and rational, without the brain; it is tho material organ of the mind, by which she communicates with the exterual world, and without *it* she is a *nonentity.* It is her sanctum-sanctorum, where she resides in mysterious silence, and cogitates on nature and revelation, bounds in thought through universal space, roams from time to eternity, and bows with adoration at the footstool of the Eternal.

To make the animal machine a little world, individualized and perfect, the external *skin* completely envelops and preserves it in complicated unity, and is beautifully finished by the almighty hand of our infinite Creator.

The animal machine is self-preserving and self-propagating. The blood circulating in tho body is deposited in minute quantities, (wherever it is required,) and supplies the bodily waste and repairs its injuries; and all the parts of the body are composed of blood. As we begin to grow old, the organs that form the blood become diseased, deteriorate its quantity and quality, and render it unfit for animal nourishment; hence the progress of decay, with advancing age. By the union of the sexes, the human race is propagated by a process, mysterious, natural and unknown.

Notwithstanding the perfection and beauty of the animal machine, there exists in its constitution a mysterious necessity for death. When *man* passes the meridian of life, he is gradually dying, and before *threescore and ten years* pass over him, his appearance indicates the progress of approaching dissolution. His hair becomes white—his brow bald—his face wrinkled—his hands shrivelled, and his feet cold. His eyes grow dim—hearing is dull—smelling imperfect—taste impaired, and the sense of touch blunted. His limbs move slowly and tottering, and he leans for support on his staff. His heart beats slow and intermits—the blood circulates sluggishly—he breathes heavy and oppressed—his bowels are inactive, and the appetite is sick. Dull, wearisome, sleepless nights creep over him, and morning returns without administering comfort to his torpid brain. He is querulous, irritable, and childish, and feels little delight in events that glide on beforo him. His *mind* broods on the past, and the recollection of his early years and departed friends haunt his torpid brain; at night on his couch, he dreams of the dead, and at noon, talks of the dead in his lonely walks. He exists the mere wreck of what he was; the summer sun sickens him, the winter wind chills him, and the eastern blasts make him shiver. His grand-children, and great-grand-children gather around him, and climb his knees—ho loves them, and tells them tales of departed years. He is the *last sad relic* of his father's house—the *lonely existing unit* that joins the *present* to the *past.* His *mind,* still pleased with her existence, sits unconcerned amid the ruin, sheds a feeble glimmer over her frail tenement, and fondly clings to its desolation. On a cold February night, the east-wind howls and inflames his lungs—he complains of a dull pain in his chest—is restless, thirsty, and feverish, picks the wool from his bed-clothes, raves of his *parents* and departed *wife,* mutters incoherent ejaculations, and *dies.*

"No sooner has he breathed his last, than those chemical agents, external and constitutional, which, when subservient to life, kept him from decomposing, now usurp the supremacy, and begin to decompose that fabric, which formerly they not only had reared, but likewise preserved; ammoniacal and inflammable gases evolve before the body be buried." If the grave is warm and dry, the body rapidly decomposes. If cold and moist, it for a long time resists putrefaction; *years pass away*—the body is fast decomposing, and shall soon return to the elements that formed it; *ages pass away*—the soft parts are decomposed, and a few crumbling bones are all that remain; *centuries pass away*—the mouldering bones have also disappeared, and nothing can be discovered and collected, of the *mysterious fabric,* that once lived, and grew, and propagated, and died. Search the grave for the wreck of *man,* who existed a thousand years ago, it is not to be found among the memorials of mortality. It has been reduced into its simple elements, and has become, in irregular succession, part of other animals, minerals, water, earth, air, and plants. The same elements that compose our

bodies may have already passed, and may yet pass through every variety of combination in nature.

Shall the *dead rise* from the grave, is an awful and mysterious subject? I will briefly dismiss it in a few words. Our almighty Creator has *promised* in his *word*, and is *able* to *raise us again* from the *dead*.

The chemical analysis of the human body teaches us that the *rich* and *poor man*, and the *lower animals*, are composed of the *same simple elements*; a *few gases* in varied combination, constitute the greater portion of the animal frame. Is it of these *gases*, that *man* is so *vain* and *proud?* Is it only to increase their *volume* that he explores every *portion* of the globe for luxuries to sate his voluptuous appetite, to add a few more *atoms* to his flesh, and a few *pounds* of *lime* to his *bones?* Let the pampered lordling who is proud of his *status*, be told, that 63 parts in the 100 of his *bones*, are composed of *lime* in combination with *acids*, and we may make him humble. Let female beauty be told that the *red* part of the blood which flushes her cheeks, is composed of *iron*, in combination with *oxygen*, and we may cure self-idolatry. Let the vain man of *genius* be told that his large, lofty, prominent brain, is chiefly composed of soda, lime, and ammonia, combined with phosphorus, oxygen, and a small portion of sulphur, and we may humble his intellectual vanity. Yet these statements are true; for they are founded on chemical analysis, that cannot err, and are as immutable and correct as mathematics. The human *mind* is immaterial and invisible, and cannot be analyzed by chemical laws,—its *composition* shall therefore remain for ever *unknown to the peasant and philosopher*.

In next chapter we will describe the skin and perspiration.

GEOLOGY.

CHAPTER I.

INTRODUCTION.—ORIGINAL CONDITION OF THE EARTH AND ITS ANTIQUITY.

Railway excursions are no way adapted for geological observation, and but little can be learned from the deck of a steamboat. If you wish to understand the structure of the earth, you must take your hammer in your hand, and peregrinate through the breadth and length of the land; ascend the hill, dive into the ravine, descend the mine, explore the river, and investigate the shore. Unless you can undergo this fatigue for the sake of truth, and the acquirement of knowledge, Geology will never completely open up her treasures to your understanding: read, and speculate, and wonder you may, but unless you are a working, you can never be a practical Geologist. But though all are not capable of undertaking this laborious task, and still fewer have time, truth is not to be hid from their understandings, and the general deductions of geological investigation may be made known. This science of late years has engaged no small share of public attention; and why so? because, more than any other science, it effects a revolution in our mode of thinking, concerning the origin of the earth and the progress of nature—discloses the secrets of a vast antiquity—unfolds the outgoings of the *Ancient of Days*, and the successive operations of his hand, even when the foundations of the earth were being laid, and through a long succession of epochs of indefinite duration.

Accustomed to consider the whole of nature as having sprung out of nothing at the Divine command in the course of a few days—and erroneously deeming this belief as essentially connected with the fundamental articles of Christian faith—it is little wonder when Hutton announced to the world that the earth afforded no trace of a commencement, nor any prospect of an end, that he was assailed as an infidel. But time effects changes in the moral as well as the physical world, and such a belief is now considered no way obnoxious to a true interpretation of the sacred text: some of our divines are amongst our most celebrated geologists, and the vast antiquity of the earth has become as fully accredited by churchmen as if it had formed a subject of distinct revelation. A few cavillers are still to be found, but not amongst the enlightened and the liberal portion of the Christian community; it is only among those who, assuming their preconceptions to be true, and their interpretations of scripture right, peril the credibility of their faith before the stubborn evidence of fact. The vast antiquity of our globe is now as fully demonstrated as its rotundity; and the lapse of ages which must have occurred in the completion of a geological epoch, as evident as the distances of the heavenly spheres: indeed more so—because the one can be proven to any person in the slightest degree conversant with the structure of the earth, by deductions the most rational and satisfactory, and by evidences the most complete; whereas in Astronomy the person who cannot apply the telescopic tube, has in a great measure to rest satisfied with the testimony of the astronomer, and the collateral evidence of the mathematician.

That the stratified portions of our earth have resulted from sedementary depositions, such as those we witness in rivers, at the mouth of estuaries, and in lakes, is evident from the vast abunance, and the perfect state in which their embedded organic remains are found. From the coral to the elephant—from the sea-weed to the lofty pine—the various species of animals and plants, attest the ancient conditions of animal and vegetable life upon the surface of the earth, during each successive period of deposition.

Coralines are found in every period, but each great division differs in the character of the species. Fishes of very different forms from those that now inhabit the ocean, with one or two exceptions, and of a predatory saurian character, prevailed in the ancient deep, and latterly crocodileans crawled upon the shores. The seas teemed with cephalopeds allied to the cuttle fishes and nautilli of the present seas; and wherever there was land a tropical vegetation arose. Seven distinct geological epochs—each characterized by sedimentary deposits of enormous thickness, and each the work of many thousands if not millions of years, and by the existence of distinct species of animals and plants—occurred previous to the introduction of an order of Nature analogous to the present; when mammiferous animals constitute the chief occupants of the land, and plants producing timber, and fruit, and flower, are everywhere to be found. Such plants were not required while land animals were few, and these principally confined to the lizard and crocodile tribes, and, therefore, they were not called into existence. *Nothing is made in vain.* But after the introduction of suck-giving animals, such as deer, cows, horses, elephants, and tapirs, which took place only after the chalk rocks had been deposited, we find the elm, the oak, and other exogenous plants to have existed, and Nature to have made a slow, but a gradual approximation to the state in which it seemed fit to Deity to call man into being.

Such is a brief outline of the views of modern geologists with respect to the age of the earth. Unfolding as they do the most evident traces of the continued exercise of creative power, in the production of creatures from time to time fitted to the existing physical conditions of the globe; they offer a most incontrovertible testimony to the existence of an infinitely intelligent and all-powerful First Cause, and thus lay the foundation of a true knowledge of the Great Architect of the universe.

That the earth is round, performs a revolution on its axis daily, and moves with inconceivable velocity in the path of its orbit round the sun once a-year, are facts now familiar to every school-boy. It is also well known that the earth is not of a perfectly round, but of a spheroidal form, its polar axis being about twenty-six miles less than its equatorial diameter. The spheroidal figure of the earth is common to that of the planetary bodies. It is that which bodies necessarily assume whose particles have free motion among themselves, when subject to a rotatory motion like the earth; hence it is inferred that the whole matter of the globe once existed in a fluid state—a supposition strongly confirmed by its other phenomena. What form the first consolidated masses assumed, whether any such now exist, we have scarcely sufficient data given us to judge; but the oldest stratified rocks, Gneiss and Mica Slate, being evidently derived from the disintegration of Granite, it is not improbable that the original mass, when first consolidated, assumed the different crystalline forms of that rock. Lyell, it is true, has carried his metamorphic theory so far as to consider Granite itself to have resulted from rocks of a prior origin, and that the tendency of all rocks, however new, is to pass onward to the metamorphic state evinced by Granite and the

These numbers written in detail as before, are

3 ten-thous. 1 thous. 8 hund. 1 ten and 4 units
1 ten-thous. 9 thous. 7 hund. 8 tens and 6 units.

Here we at once perceive that we cannot proceed as in the last example, for 6 units are more than 4 units, and 8 tens than 1 ten, and further on we find 9 thous. standing beneath 1 thous. But recollecting that we may add the same number to *both* of the given numbers, without altering their difference, (and the difference is that which we are in quest of,) we proceed to apply the principle in this manner: add ten to the 4 units of the upper line, making 14 units, and one to the 8 tens of the under lines, making 9 tens; so that the numbers will now read

3 ten-thous. 1 thous. 8 hund. 1 ten and 14 *units*,
1 ten-thous. 9 thous. 7 hund. 9 *tens* and 6 units.

Again, add 1 hund. = 10 tens to the 1 ten in the upper line, making 11 tens, and 1 hund. to the 7 hund. of the under line, making 8 hund. so that now the numbers will read

3 ten-thous. 1 thous. 8 hund. 11 *tens* and 14 *units*,
1 ten-thous. 9 thous. 8 *hund.* 9 *tens* and 6 units.

Lastly, add 1 ten-thous. = 10 thous. to the 1 thous. of the upper line, making 11 thous. and 1 ten-thous. to the 1 ten-thous. of the under line, making 2 ten-thous., so that the number will read

3 ten-thous. 11 *thous.* 8 hund. 11 *tens* and 14 *units*,
2 *ten-thous.* 9 thous. 8 *hund.* 9 *tens* and 6 units.

Now, these numbers are not the same as those given; but we know that their difference must be the same since we have made exactly the same additions to each; and by subtracting the one from the other, as we did in the first example, we get as the difference sought

1 ten-thous. 2 thous. 0 hund. 2 tens and 8 units,

that is 12028. Therefore $31814 - 19786 = 12028$, and the proof is, that $19786 + 12028 = 31814$.*

We may now imbody these processes in a rule, as follows :—

I. *Write the number which is to be subtracted*, (which is of course always the lesser of the two and is called the SUBTRAHEND,) *under the other*, (which is called the MINUEND,) *so that its units may fall under the units of the other, the tens under the tens, and so on.*

II. *Subtract each figure of the lower line from that above it, if that can be done. When that cannot be done, add* 10 *to the upper figure, and then subtract the lower figure, but when that is done, recollect to add* 1 *to the next figure in the lower line before subtracting it from its corresponding figure in the upper line.*

EXAMPLE.—Find $867543267 - 164567345 = ?$

Arrange the numbers as directed in I. of the rule. Here $7 - 5 = 2$; $6 - 4 = 2$; $2 - 3$ is impossible, but $12 - 3 = 9$, and carry 1; then $3 - (1 + 7) = 3 - 8$ is again impossible, but $13 - 8 = 5$ and carry 1; $4 - (1 + 6) = 4 - 7$ is also impossible, but $14 - 7 = 7$ and carry 1; $5 - (1 + 5) = 5 - 6$ is also impossible, but $15 - 6 = 9$ and carry 1; $7 - (1 + 4) = 2$; $6 - 6 = 0$; and $8 - 1 = 7$.

Minuend	= 867543267
Subtrahend	= 164567345
Remainder	= 702975922

The work is readily proved by adding together the remainder and subtrahend, the sum of course should be the minuend.

The following instances may now be verified for the sake of exercise :—

33758317658	8756789675436
21869433245	7900976080978
11888884413	855813594458

Should there not be as many figures in the under line as there are in the upper one, the deficiency may be *actually* made up with ciphers; but it saves trouble to proceed without writing them, simply bearing in mind that the line may be so extended.

This direction is founded on the evident fact, that a number is not altered in value by placing ciphers on the left of it. Thus, 321 is the same as 00321, for it means

3 hundreds, 2 tens, and 1 unit,

and 00321 means in reality nothing more; for

0 ten-thousands, 0 thousands, 3 hundred, 2 tens, and 1 unit,

merely differs in saying that the number contains no tens of thousands, and no thousands. It would be very different, however, were the ciphers placed on the right; for then the 3 would become tens of thousands, the 2 would be thousands, and the 1 would mean a hundred, and the ciphers would denote that there were no tens or units. The following are instances in which these remarks are applicable :—

8360000	1842007	30000680
6756	90009	9091
8353244	1751998	29991589

When two or more numbers are given to be subtracted from two or more other numbers, it is *generally* best to add together all those belonging to the minuend, and then all those belonging to the subtrahend, and to take the sum of the one set from the sum of the other; thus,—

From $675 + 70 + 1211 + 673$, subtract $31 + 910 + 76 + 106 + 78$.

Here, $675 + 70 + 1211 + 673 = 2629$; and $31 + 910 + 76 + 106 + 78 = 1201$;

Then, $2629 - 1201 = 1428$.

Find the difference between $6173 + 95 + 78$, and $867 + 712 + 81$. *Answer*, 4686.

What is $2572 - 183 + 17856 - 1273 + 534$? *Answer*, 19506.

There is an expeditious and elegant mode of subtracting numbers by means of what is called the *arithmetical complement*. It is not taken notice of in our elementary treatises on arithmetic, because it requires the learner to know something about the principle before he can practise it with success, and this is reckoned superfluous in the *art of ciphering*. We shall try to make it plain.

Let it be required to find $1000 - 732$. The answer, by the common rule, is 268; but we shall obtain exactly the same result by subtracting the units from 10, and the other figures successively from 9.†

Thus, $10 - 2 = 8$; $9 - 3 = 6$; and $9 - 7 = 2$.

We may therefore state it as a rule, that *to subtract a number from* 1, *followed by as many ciphers as the number has figures, the figure in the unit's place must be subtracted from* 10, *and the others from* 9 :

Thus, $1000000 - 708367 = 291633$.

This process, which is so easy that it scarcely deserves to be counted an operation, is made use of for our purpose in the following manner :—

Let the difference $3487 - 259$ be required.

It is here evident that by decomposing 3487 into $2487 + 1000$, the difference between it and 259 is not altered, and we shall have

$2487 + 1000 - 259$; but $1000 - 259 = 741$;

Therefore, $2487 + 1000 - 259 = 2487 + 741 = 3228$.

Thus, instead of subtracting 259, we have, in fact, added 741, and all cases of subtraction may be reduced to cases of addition in the same way. The following subtractions may be made by this mode, and then we will show how the rule may be somewhat shortened.

$1660 - 786 = 874$ $4686 - 996 = 3690$.

All that is necessary to the shortening of the process, is the admission of this principle : *the difference between two numbers is not altered by adding a number to it, if at the same time we subtract the same number from it.* Let this number always be 1, followed by as many ciphers as the number to be subtracted has figures.

Thus, suppose it is required to find the difference $9846 - 635$.

* We might have considered the case differently, and have arrived at the same result without these successive additions; thus,

31814 may be written 2 ten-thous. 11 thous. 7 hund. 10 tens and 14 units.
19786 as before 1 ten-thous. 9 thous. 7 hund. 8 tens and 6 units.

and taking the one from the other, we get as before,

1 ten thous. 2 thous. 0 hund. 2 tens and 8 units.

The method shown in the text, however, leads more directly to the common rule, which we believe to be preferable to that founded on the method shown here. If either of the methods, however, be understood, there will be no difficulty in understanding the other.

† This is the principle noticed in the note preceding; for 1000 = 9 hundreds, 9 tens, and 10 units.

Here, by adding 1000 and subtracting 1000, we get

$$9846+1000-635-1000\,;$$

But, by performing the operation 1000—635, we get

$$9846+365-1000.$$

Now, all that remains to be done is, to add 365 to 9846, and to subtract 1 from the thousands of the result; but we might put the 365 in place of the ciphers in 1000, provided we put some mark upon the 1 to show, that while the other figures are to be added, that this one is to be subtracted. This is done by placing a dash, answering to the sign of subtraction, over the 1, making it $\bar{1}$, and making $365-1000$ into $\bar{1}365$. This artifice will convert the above expression into

$$9846+\bar{1}365=9211\,;$$

a calculation which is otherwise shown in the margin.

$$\begin{array}{r} 9846 \\ \bar{1}365 \\ \hline 9211 \end{array}$$

The quantity $\bar{1}365$, is what is called the *arithmetical complement* of 635; and generally to find the arithmetical complement of any number, we must subtract the units' figure from 10, the others from 9, and place 1 on the left of the result. It will also be observed, that *this complement, added to the number, gives* 0 *for the sum.* Thus $635+\bar{1}365=0000=0$. Farther, *every case, where it is required to subtract a number we may add its arithmetical complement.*

As we can readily perform such subtractions as 1000—635 mentally, in fact, as quickly as we can write the figures, the arithmetical complement furnishes us with a very neat and expeditious way of taking the balance of a successive set of additions and subtractions. For instance,—

$$32731+5729-371-4834,$$

takes the form shown in the margin; the complement of 371 being $\bar{1}629$, and that of 4834 being $\bar{1}5166$; the $\bar{1}$'s in the columns must of course be subtracted as before shown.

$$\begin{array}{r} 32731 \\ 5729 \\ \bar{1}629 \\ \bar{1}5166 \\ \hline 33255 \end{array}$$

Presuming that the preceding principles are well understood, we may now show how sufficient exercise upon them may be obtained, without putting ourselves to the needless trouble of writing such columns of "questions for exercise," as we usually find in books. Let the *industrious* student take a series of numbers, each containing one figure more than the preceding one; say 271, 3567, 46891, 506798, 9763897, and 85438796; and let him subtract each preceding number from that which follows it; thus—

3567	46891	506798	9763897	85438796
271	3567	46891	506798	9763897
3296	43324	459907	9257099	75674899

Let him then add all his results together, with the least number chosen, and, if his work be correct, the final result will be the greatest number. The completion of the operation is shown beneath.—

$$\begin{array}{rr} \text{Differences}= & \left\{\begin{array}{r} 75674899 \\ 9257099 \\ 459907 \\ 43324 \\ 3296 \end{array}\right. \\ \text{Least number}= & 271 \\ \hline \text{Greatest number}= & 85438796 \end{array}$$

We hope that the student, who has here approached the subject for the first time, has found the preceding chapter rather difficult; if he has found it very easy, we advise him to examine it again, for we very much suspect that he has not thoroughly understood it. We might indeed state it as an axiom, that those students who find the greatest number of difficulties in learning mathematics, make the best mathematicians; and conversely, those who find the study exceedingly easy, rarely arrive at any degree of proficiency. The reason is obvious: the one class are *thinkers*, and the other *believers;* the former must see that all is fairly demonstrated, the latter care not for the demonstration of anything.

ANATOMY AND PHYSIOLOGY.

CHAPTER II.

THE SKIN AND PERSPIRATION.

The skin is composed of four coats, the external, two middle, and the internal. 1st. The external coat is a thin cuticle, or scarf skin, endued with little sensibility, intended for a covering to the body, to protect it from outward irritation, and shield it from immediate contact with the material substances and elements that surround it. It is full of pores, covered with scales, perforated by the extremities of the perspiring and absorbing vessels, the ducts of the glands of the internal skin, and by the hairs. The nails and cuticle are connected, and in diseases of the skin, if the cuticle exfoliates, the nails are also pushed off; and after death, they *both* separate from the true skin underneath them, by maceration and putrefaction. The cuticle and nails are equally destitute of nerves and sensation. The nails are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen, and contains a little phosphate of lime. Horns and nails have nearly the same component parts. The cuticle projects over the roots of the nails. The nails do not become scaly and exfoliate like the cuticle; they grow from a root like the hair, though they are evidently a continuation of the cuticle. The hairs grow from bulbous roots, situated in the cellular membrane, beneath the cuticle. The bulb is vascular, and connected by vessels with the cellular tissue. It consists of a double membrane, and the cellular texture lying betwixt them is filled with a bloody fluid. The hair arises from the bottom of the internal sac, and when a hair is extracted, if the sac or bulb be left entire, it will be regenerated. The European has the longest hair; the Asiatic next; thirdly, the American; and lastly, the African: men of a dark sallow complexion are generally hairy on the breast and shoulders. There is very little difference in the growth of hair and wool; wool grows thickest in summer, and finest in spring and autumn; the fleece becomes coarse and hairy in a warm climate. A hair appears to be a kind of tube enveloped in a cuticle, its surface is covered with scales; hence its disposition to entangle with other hairs. A hair which is soft and flexible, and loses its curl in moist weather, parts easier with its gelatine than a strong elastic hair, which retains its curl, and parts with its gelatine in small quantities, with difficulty. Black hairs are composed of an animal matter, which constitutes the greatest proportion,—a white solid oil, small in quantity; a grayish green oil, more abundant; iron, the state unknown; oxyde of manganese, phosphate of lime, carbonate of lime, very scanty; silica, and sulphur.

The human cuticle is white, and does not vary its *hue* in different individuals. It is as *colourless* in the African, as in the European; in the American Indian, as in the Asiatic. This fact may be easily proved, by a very simple experiment. If we apply a cantharides blister to a white man's skin, it raises the cuticle, by causing a fluid called the serum, to form underneath it; now the skin, raised by the blister, is the external *white coat*, which I am describing. If you apply a blister to a negro's skin, the cuticle (or external coat,) which rises up and covers the serum, is also *white*, as white as the cuticle of a Scotchman. This experiment proves, that it is not the external cuticle which makes the negro black; for his outward skin, or cuticle, is as white as the European's. The varied coloured skins of different individuals arise from other natural causes, which I will briefly explain, when describing the second coat. The cuticle is chiefly composed of a modification of coagulated albumen: coagulated albumen is that tasteless substance, which constitutes the outward portion of a boiled egg. In the negro, the internal surface of the cuticle is darker and softer than the external.

The second, or mucous coat, lies in immediate contact with the upper, and is composed of numerous blood-vessels and nerves, which give it exquisite sensibility. You cannot touch any part of your body where the cuticle is thin, without feeling a sensation of contact with the second coat. It is white in the European, and also in the infant negro, for about

six days after his birth. It then begins to secrete a dark coloured fluid upon its surface, which in the negro becomes black, and remains, *in statu quo*, until he dies and decomposes into his natural elements. This dark coloured secretion, shining through the thin external cuticle, gives the black hue to the African's skin. This secretion is *yellow* in the Asiatic, *red* in the American Indian, and *pale* in the European. The *thickened* cuticle on the palms of the negro's hands and the soles of his feet, by its obtuse opacity prevents this black secretion from shining darkly through it, and makes his thickened palms and soles appear much *whiter* than the rest of his sable body. The African's hue appears blackest on those parts of his body where the cuticle is thinnest. It is the pale secretion of this coat that makes the albino:* and its bilious secretion caused by obstructed bile, mingling with the circulating blood, makes the white man's skin appear yellow in jaundice. The varied secretions of this sensitive coat, modified by climate, constitution, and circumstances, give different colours to the different tribes of mankind. The physical causes of the varied coloured secretions of this mucous coat are not very accurately understood by physiologists. It cannot be the intense *heat* of the African's torrid climate *alone* that has made his skin so *black;* for the Esquimaux and Greenlanders are nearly as *dark* as negroes, although they live in an arctic climate of perpetual ice and snow; nor can it be *cold alone* that produces the sable skin; for the Finlanders and Norwegians, who live farther *north*, and in *colder* wintry climes than any of the inhabitants of the continent of Europe, are fairer in complexion than any one of them all. The South-American Indians, who live on the summits of the Andes, exposed to perpetual cold, ice, and snow, are as dark in complexion as the inhabitants of the burning valleys beneath them, who luxuriate in indolence, on the soft, warm, flowery lap of everlasting summer. Something must be attributed to domestic and social habits, as well as to external circumstances; the face of the Highland peasant *girl* is dark-*brown;* the Highland *lady* is *white*. The constitutional diathesis of different families, tribes, and nations, is modified by education, political, domestic, and social circumstances, and physical causes; and *these* may produce all the varieties of complexion that distinguish individuals, families, and nations, from each other. Any one of these causes cannot *alone* induce all these changes; but the *whole, combined* and modified *individually* by their separate and *mutual* action on each other, may have produced every variety of complexion in the human species. In the negro, the inner part of the second coat is blacker than its outer surface.

This coat is also the seat of the pleasure and pain communicated by the sense of touch. It gives us painful sensations when irritated by external injuries; and pleasurable feelings, when stimulated by gentle contact with delightful objects. Its cruel laceration, from external violence, makes the sailor, the soldier, and slave, shrink with agony, when smarting under the infliction of the ignoble lash. It is also the sexual seat of pleasure in mutual kissing. The cold winter storm beating on its nervous sensibility makes us shiver. The summer sun, shining on its delicate *nerves*, makes us languid; without *it*, *man* would be incapable of appreciating pleasure and pain, by the sense of touch and contact with external bodies; and merely *exist* without sweet enjoyment. The earth, unadapted to his physical constitution, would be to *him* a dreary wilderness, where plants and lower animals alone could multiply and grow, and over-run its surface. But God, who adapts the *means* to the *end*, has made all things *right*. And every *person*, who understands the mechanism and physiology of his skin, will feel gratitude to the Eternal, and praise *Him* for *having made us as we are*.

Underneath the second, lies the third, or vascular coat. It is full of minute blood-vessels, and is best demonstrated when acutely inflamed. It is sometimes very much thickened by increased vascular action, and then it may be distinctly seen and examined, by ordinary spectators. It is the seat of the blood-vessels of the skin, and gives the red appearance to the cheeks, lips, and other parts of the body, where the external coverings are thin. It is the seat of the pustules of small-pox, with many other cutaneous diseases, especially those of an inflammatory nature, induced by extraordinary vascular action. In cases of *extreme debility*, such as typhus fever, purpura, measles, &c., it is the seat of the petechiæ, (or dark spots,) that appear like dots in the skin. These spots are caused by its minute exhausted vessels permitting more blood to escape, than its feeble absorbents are able to return quickly into the system; and they always indicate *morbid* debility. If these spots are formed of *venous* blood *alone*, the physical *debility* is not so extreme as when they are composed only of *arterial* blood; when venous blood is effused, they are darkly-purple; when arterial blood is effused, they are bright red, like scarlet, and are always a dangerous symptom, in the last stages of typhus gravior, if the patient belongs to the lymphatic temperament.

Beneath the third coat, lies the fourth, the cutis vera, (or true skin.) This is the thickest layer, and in lower animals is tanned to make leather; after death it is stripped from some of our larger domestic quadrupeds, and tanned for the purpose of making into shoes. In some monstrous wild animals, such as the hippopotamus and rhinoceros, it is so very thick, that it cannot without difficulty be pierced by an ordinary musket-ball. The true skin of the giraffe is an inch and a half thick. In the magatherium, an extinct animal that existed and perished *long* before the creation of *man*, it was more than two inches. This fact is not only demonstrated by many petrifactions of those animals' skins that have been found by geologists in the rocks that compose the interior strata of our globe; but also from the actual carcass of an entire animal, found a few years ago, imbedded in a deep layer of everlasting frozen snow, on the lofty bleak coast of Russian Siberia, and where it must have been buried by accident, at some remote undefined period of the ancient world; the icy grave was first disclosed by a large part of the coast falling on the beach, and leaving the animal exposed. The *cutis vera* binds down the soft parts of our bodies, protects them from violence and external accidents, and preserves their beauty, form, and symmetry, without any ungentle compression, nor does it irritate the most delicate organs that lie underneath it. Its composition appears to be a peculiar modification of gelatine, or animal glue.

There is another important use for the skin in the animal economy, than merely an external covering to the body. It is the organ by which perspiration is performed; and is, therefore, necessary for the continued vitality and health of our species, and of every animal that perspires.

Perspiration (or *sweating*,) is an excrementitious evacuation that requires to be constantly exhaled from the body, to free the blood from impurity, and to preserve animal life from immediate disease and premature death. About five pounds avoirdupois of perspired matter pass through the skin of a full-grown man every twenty-four hours.

There are two kinds of perspiration, sensible and insensible. The *sensible* can always be felt and perceived; for it constitutes visible *sweating*. The *insensible* passes off in the form of a *gas* or *vapour*, and we are not so conscious of its constant evaporation. Sweating is a secretion of the internal coats of the skin, which passes through the external *cuticle* by innumerable minute pores, imperceptible to the human eye, except by the help of a large microscope. When we see a person covered with large drops of *sweat*, we may rest assured that *they* have all passed through these *minute pores;* but having been perspired quicker than exhaled, they have accumulated on the surface, and are glistening on it like blobs of dew. Persons in this condition should not expose their bodies suddenly to a cold damp atmosphere; for *cold* causes the large drops to coagulate, closes the pores of the cuticle, and obstructs perspiration.

If we live in a cold atmosphere, where our perspiration is checked, our vital heat is retained. If in a warm atmosphere, where our perspiration is profuse, the heat of the body is discharged; hence the varied quantities of perspiration exhaled in warm and cold atmospheres help to equalize our animal heat, and make it suitable to the exigencies of the different climates to which we are exposed. The skin sympathizes with the lungs, bowels, and other internal organs, and generally renders them healthy or diseased, (in combination with other causes,) proportioned to the sanity, or morbidity of its natural functions.

The perspired matter is principally composed of water and carbon. It also holds in solution several salts and animal matter. The oxygen of the atmosphere, combining with the carbon, forms the carbonic acid thrown off by perspiration. Besides the *insensible* perspiration, there is also an *oily exudation* of the *glands* of the skin, which appears to be useful in giving pliancy and softness to the scales of the cuticle. This oily secretion is very

* The albino is a white negro. The pale secretion of the muscous coat of his skin, which makes him white, is diseased.

from the multiplier to the multiplicand and product, which are at some distance; this materially increases the risk of errors, and renders it almost always essentially requisite to do the work twice over where the result is important.

ANATOMY AND PHYSIOLOGY.

CHAPTER III.

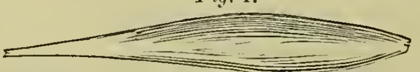
THE MUSCLES AND MUSCULAR ACTION.

I. *A General Description of the Mechanism and Uses of the Muscles.*

A MUSCLE is composed of long slender fibres, which possess the power of contracting, and are everywhere enveloped in common cellular membranes; the fibres become fewer as they approach the extremity of the muscle, and ultimately terminate. The cellular substance (that envelops them) being thus freed from the muscular fibres joins more closely together, and forms itself into a white round ropy or flattened tendon—when the muscular fibres contract, their power is united on the tendon, and drawing it up, make it perform the action of a pulley. Tendons are therefore composed, not of muscular fibres, but of the cellular substances with which the fibres are enveloped. Every muscle is supplied with arteries, veins, lymphatics, and nerves; for without these they could neither grow, renew, nor contract. Their vital power is derived from their nerves.

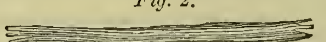
Muscles are of two kinds, simple and compound. The simple are called ventriform, when their bellies are large, but diminish in size as they approach their tendons. Fig. 1. They are

Fig. 1.



called parallel, when their fibres terminate in a broad fibrous web, without tendons. Fig. 2. They are penniform, when their

Fig. 2.

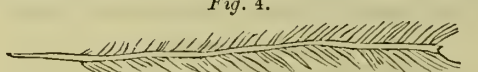


fibres run parallel, but oblique to their tendons, like feathers on one side of a quill. Fig. 3. They are double-penniform when

Fig. 3.

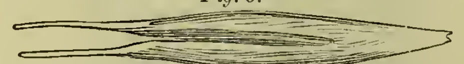
two ranges of parallel fibres pass obliquely into a tendon running along their centre. Fig. 4. They are double-bellied where they

Fig. 4.



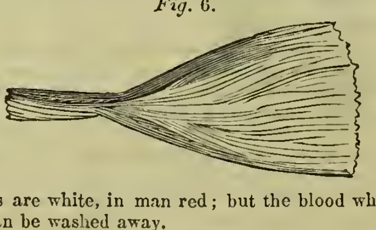
have two bellies meeting, and inserted into one tendon. Fig. 5.

Fig. 5.



They are called fan-shaped, when they are broad and thin at the origin, and thick at its insertion into the tendon. Fig. 6. In fishes,

Fig. 6.



the muscles are white, in man red; but the blood which makes them red can be washed away.

Different muscles accomplish very different purposes. 1st. They envelop, compress, and sustain, the viscera, or internal organs of the abdomen, or belly. 2d. They lengthen, shorten, or compress, some organ or organs—such as the tongue, &c. 3d. They widen, or contract, some opening,—as the sphincter muscles do, at the entrance of the natural passages of the body. 4th. They roll, or move, the organs of the senses,—such as the eye, ear, &c. 5th. They relax, pull up, or make rigid, a valve, as the epiglotis; a septum, or division of parts, as the velum pendulum palati, or vail of the palate, &c, 6th. When they are inserted, or attached to bones, we perform by their action, locomotion, as walking, running, leaping, dancing, &c. Some of the tendons are flat and broad like a web,—others radiate and spread out into digitations like fingers,—and some are loug and round, like cords.

The muscles, especially of the extremities, are, in general, either flexors, extensors, pronators, adductors, abductors, or rotators. The flexors bend, or draw down the limb, or the part to which they are attached, if it has a moveable joint, and are placed under that part of the body on which they act, as antagonists to the extensors. The extensors raise, elevate, and extend, the moveable parts to which they belong, and are placed on the superior surface, as antagonists to the flexors. Some muscles move the parts obliquely, as the oblique muscles of the eye—some make them describe a semicircle, as in the motions of the neck, arms, and legs, &c.—some elevate the parts, as the upper eyelids, &c.; others contract them, as the eyebrows; or corrugate them, as the extremity of the lips—some are abductors, and others adductors, as in the legs, arms, fingers, toes, &c., moving them to either side. Some are supinators, and others pronators, as in the forearm and fingers, &c.—some are transverse, others straight, oblique, or pyramidal, as on the abdomen or belly, &c.—some are erectors, others ejaculators, as in the sexual and seminal organs—some are half-membranous and half-tendinous—as in the legs, &c. In short, muscles are as varied in form as in action, and perfectly adapted to the wise purposes for which the Great Architect of the universe has inimitably formed and designed them, in the sublime and beautiful mechanism of the living animal machine.

II. *The Difference betwixt Muscular Power, and Nervous Sensibility.*

The vital power of a muscle resides in the nerves, and is nervous. Its irritable power is the property by which it feels and acts, when stimulated without consciousness. It is an inherent principle, and belongs to its constitution, and remains for some time after death. Ligaments and tendons support the same weight, whether dead or alive; but a living muscle, that lifts 100 lbs. with ease, cannot, after death, raise 20 lbs. without danger of rupture. When a muscle is newly cut from a limb, it palpitates and trembles for a considerable time—it cannot be nervous power that thus makes it irritable; for the nerves being separated from their origin are dead and powerless. If the heart is newly separated from the body, it contracts if irritated. The bowels continue their peristaltic motion after death, until they become stiff and cold—even in vegetable life, as in the sensitive plant, this contractile power is visibly exhibited. It is not nervous power; for it belongs absolutely to the muscle, and exists in some cases without nervous vitality altogether—hence there is a distinction betwixt nervous sensibility, and muscular irritability. The former dies immediately with the animal; the latter lives for a short time after the animal is dead. Muscles are irritable and contractile by the inherent principle of their fibres, and are sensible by the vitality communicated through their nerves. Though nerves are sensible, they are not contractile, and cannot perform the functions of muscular fibres.

The muscles are of two kinds—voluntary and involuntary; the heart is stimulated involuntarily by the circulating blood—the stomach by food—the bowels by their contents—the kidneys by urine—the genital system, by sensual appetite—and the womb by its fœtus. But the voluntary muscles are stimulated by the nerves, and obedient to our will—we lift our hands and arms—jump and walk—dance and sing—because we will them. The muscles of these parts are therefore voluntary; but the heart moves without our will, and is therefore an involuntary muscle. The nerves do not move like muscles under the influence of stimuli—they only convey the impressions or commands betwixt

MUSCLES OF THE HUMAN BODY

Fig. 1.

1. Occipito frontalis.
2. Atollens aurem.
3. Anterior auris.
4. Orbicularis palpebrarum.
5. Compressor naris.
6. Levator anguli oris.
7. Levator labii superioris alæque nasi.
8. Zygomaticus major.
9. Zygomaticus minor
10. Masseter.
11. Depressor anguli oris.
12. Sterno cleido mastoideus.
13. Depressor labii inferioris.
14. Orbicularis oris.
15. Platysma myoides.
16. Extensor digitorum communis.
17. Extensor carpi radialis longior.
18. Extensor carpi radialis brevior.
19. Abductor indicis manus.
20. Deltoides.
21. Biceps brachii.
22. Pronatur radii teres.
23. Supinator radii longus.
24. Flexor carpi ulnaris.
25. Flexor carpi radialis.
26. Palmaris longus.
27. Aponeurosis palmaris.
28. Abductor pollicis manus.
29. Palmaris brevis.
30. Flexor sublimus perforatus.
31. Pectoralis major.
32. Obliquus descendens externus.
33. Linea semilunaris.
34. Linea alba.
35. Poupart's or Fallopius' ligament.

36, 36. Sartorius.

37. Tensor vaginæ femoris.
38. Gracilis.
39. Iliacus internus.
40. Pectinalis.
41. Triceps adductor femoris.
42. Psoas magnus.
43. Vastus externus.
44. Vastus internus.
45. Rectus.

46, 46. Tibialis anticus.

47. Extensor longus digitorum pedis.

48, 48. Extensor proprius pollicis pedis.

49. Malleolus internus.

Fig. 2.

1. Corrugator.
2. Temporalis.
3. Masseter.
4. Buccinator.
5. Orbicularis oris.
6. Depressor labii inferioris.
7. Levator anguli oris.
8. Sterno cleido mastoides.
9. Extensor ossis metacarpi pollicis manus.
10. Extensor primi internodii.
11. Extensor secundi internodii.
12. Indicator.
13. Abductor indicis manus.
14. Flexor sublimus perforatus.
15. Lumbricalis.
16. Flexor ossis metacarpi pollicis.
17. Abductor minimi digiti manus.
18. Flexor parvus minimi digiti.
19. Sterno hyoideus.
20. Biceps brachii.
21. Pectoralis minor
22. Serratus magnus.
23. Obliquus ascendens internus.
24. Pyramidalis.
25. Rectus abdominus.
26. Iliacus internus.
27. Psoas magnus.
28. Pectinalis.
29. Triceps adductor femoris.
30. Gracilis.
31. Vastus externus.
32. Cruralis.
33. Vastus internus.
34. Ligamentum patellæ.

35, 35. Exteusor proprius pollicis pedis.

36, 36. Extensor longus digitorum pedis.

37, 37. Malleolus internus.

Fig. 3.

1. Temporalis.
2. Occipito frontalis.
3. Platysma myoides.
4. Sterno cleido mastoideus.
5. Trachelo mastoideus.
6. Splenius.
7. Deltoides.
8. Biceps brachii.
9. Brachialis internus.
10. Supinator radii longus.
11. Triceps extensor cubiti.
12. Trapezius seu cucullaris.
13. Latissimus dorsi.
14. Serratus magnus.
15. Obliquus descendens externus.
16. Gluteus maximus.
17. Gluteus medius.
18. Sartoris.
19. Vastus internus.
20. Vastus externus.
21. Rectus.
22. Tendon of the biceps muscle, forming the outer ham-string.
23. Tendons of the semimembranosus, and semitendinosus muscles, forming the inner ham-striug.
24. Gastrocnemius externus.

25, 25. Peroneus brevis.

26. Extensor longus digitorum pedis.
27. Extensor brevis digitorum pedis.
28. Plantaris.
29. Gastrocnemius.
30. Tendo achillis.

Fig. 4.

1. Occipito frontalis.
2. Temporalis.

3, 3. Trapezius seu cucullaris.

4. Sterno cleido mastoideus.
5. Deltoides.
6. Extensor ossis metacarpi pollicis manus.
7. Extensor primi internodii.
8. Extensor secundi internodii.
9. Extensor digitorum communis.
10. Triceps extensor cubiti.
11. Extensor digitorum communis.
12. Latissimus dorsi.
13. Gluteus maximus.
14. Biceps flexor cruris.
15. Semitendinosus.
16. Semimembranosus.
17. Gastrocnemius.

18, 18. Peroneus brevis.

19, 19. Peroneus longus.

20, 20. Tendo achillis.

Fig. 5.

1. Temporalis.
2. Complexus.
3. Splenius.
4. Levator scapulæ.
5. Rhomboideus minor.
6. Supra spinatus.
7. Serratus superior posticus.
8. Rhomboideus major.
9. Infra spinatus.
10. Triceps extensor cubiti.
11. Extensor primi internodii.
12. Extensor secundi internodii.
13. Indicator.
14. Serratus posticus inferior.
15. Gluteus medius.
16. Obliquus ascendens internus.
17. Biceps flexor cruris
18. Semitendinosus.
19. Semimembranosus.
20. Plantaris.

21, 21. Gastrocnemius internus.

22, 22. Gastrocnemius externus, part cut off.

23, 23. Tempo acuillis.

Fig 3

Fig 4

Fig 5

MUSCLES OF THE HUMAN BODY

our will and our muscles; but the muscles alone possess a contractile power, and employ it—nervous power is sometimes exhausted and apt to change; muscular power is always perfect, and ready to act when stimulated, in obedience to our will—but the muscles soon lose their contractile power, when deprived of sensibility by paralysis of their nerves. The involuntary muscles are mechanically stimulated without our control—the voluntary are put into action by the impulses of the mind, and are under our arbitrary commands. The nerves of feeling and motion in the extremities come from the spinal cord. The muscles of the body are double, and on each side equal in number, action, and power; the muscles on one side balance the muscles on the other. If on one side they are paralyzed, and cannot contract, those on the other, exerting their usual strength, destroy the balance of power—in palsy of one side of the face, this fact is visibly illustrated. If a joint be dislocated, the action of the muscles is violent and spasmodic till it be reduced; nervous influence is therefore the stimulus of the voluntary muscles—mechanical agents stimulate the involuntary. If a man be suddenly killed, the irritable power of his muscles survives his nervous sensibility; for his flesh trembles, and his absorbents continue their function, for a while after he is dead, and his nervous power annihilated. In cases of suffocation, we sometimes restore animation after the nervous sensibility is suspended, and when nothing is left to aid our experiments, but muscular irritability. If putrefaction has commenced, the irritable power of the muscle is for ever gone, and nothing can restore it. Sensibility therefore depends on the nerves—motion on the muscles; the one conduces to our pleasures and pains, and is connected with our intellect—the other is the prime support of animal life, and the source of corporeal power—yet both are necessary in the living animal, to produce locomotion.

The length of the lever increases the mechanical power of the muscle—the mastoid process laterally, and the occiput posteriorly, are levers for the head—the spine of the vertebræ for the back—the olecranon or elbow for the arm, and the pisiform bone for the hand—the pelvis or basin, and the trochanters of the thighbones, are levers for the thigh—the patella or kneelid for the leg—the heelbone for the foot, and the arch of the foot for the toes. These are the principal, but not all the levers of the body.

In all the other muscular implantations, the ends of the muscles are levers, not behind the joint; but betwixt the joint and the body to be moved. There is a greater loss of power when they are inserted near a joint, and there is less loss of power, when a tendon is fixed far from a joint; for although such insertions be designated shorter or longer levers—yet there is always some mechanical loss of power, and true levers in the body are very few indeed. Nature has provided as much contractile power in the muscular fibres, as to compensate for the loss in effect of the lessened mechanical power of the levers; and in place of increasing the effect of muscles by levers, pulleys, and hinges, there is in almost every muscle, a great abatement of its force, by the form of the bone it is designed to move; for muscles lose much of their effect by implantation, not behind the joint, but betwixt the joint and the body to be moved, and their oblique insertion, with regard to the motion about to be performed; and half their power is lost, on the immovable end of the bone. In the human body, muscular power is always sacrificed to preserve the form and symmetry of the parts, to make the joints smaller than the limbs, and proportion the limbs to the body. Extraordinary lever power is not often required in the motions and actions of the body; for the great Creator has appointed sufficient vital and contractile power in the muscles, to effect every useful purpose, and at the same time preserve the beauty and mechanism of the animal machine, according to his plan of infinite wisdom, and almighty power.

III. *The Adaptation, Uses, and Diseases of the Cellular Substance of the Muscles and Joints of the Body.*

The active parts of the system are the muscles and nerves—the muscles, to move the body and perform its offices, each submitting to its own peculiar stimuli, and most of them obeying the will,—the nerves, to feel, suffer, enjoy and issue the commands of the will, and to move the muscles to action. The muscles possess their own peculiar kind of vitality independent of the nerves. But there is a substance called the cellular substance, which not only binds and separates the muscular fibres and muscles individually and collectively, but forms coverings for the brain and nerves—sheaths for the muscles, tendons, ligaments, bursæ, and all the apparatus of the joints, and unites them into a whole, by the extensions, divisions, and duplications of its own proper substances. Tendons, or the extremities of muscles—ligaments, or the sinews—periosteum, or the membrane that covers the bones—and the bursæ, or the mucous bags that fill up and lubricate the cavities of joints,—are composed of this cellular substance, which not only combines and connects the parts by its elasticity, but is also a medium of communication for the rest of the system. The cellular substance keeps the muscles and their fibres separated at proper distances from each other, and lubricates and supports them. Its thinner halitus makes them play easy and free; and its fat (for the cellular substance contains the fat of the body,) not only supports them in their action, but preserves their softness, and lubricates them so perfectly, that its deficiency is painful, and its superabundance cumbersome to the individual. When muscles rub on each other, the halitus (or dewy softness) of the cellular substance prevents friction and pain; when tendon rubs on tendon—bone on bone—or muscle on tendon—the cellular substance assumes another form, and its little cells running together into one large cell, with a thicker and more copious exudation, and being literally bedewed with a gelatinous mucus—prevents the bad effects of friction. These large cells are called bursæ mucosæ, and are placed under rubbing tendons, and in large joints, to prevent friction, as circumstances require them. Every muscle is enclosed in its own cellular sheath, not only to give it pliancy, strength and form, but to preserve it in its proper position.

Tendons are not only necessary as pulleys to the bones, but to give the limbs a proper form, and preserve their beautiful symmetry. Tendons are seldom required, except where muscles are inserted into bones. There is no tendon in the heart, the stomach, the bowels, the œsophagus, and bladder; these do not require them; for their motions are wholly contractile, and need no lever power. But where tendons pass over bones and traverse joints, their force is concentrated into narrower bounds, and their long cords being fixed to the extremities of the muscles, pull the bones and raise them in obedience to our will. Tendons have no visible nerves, and have little feeling and no motion. The expansion of the palmaris, and many other tendons, may be unravelled into simple cellular substances. The periosteum, or membrane which surrounds the bones, is also a condensation of cellular substance, in successive layers, attached to the bones.

Tendons are implanted into the periosteum, mix with it, and become part of its substance. The tendons of muscles sometimes separate and form sheaths or rings for others. Sometimes they run in grooves formed in the bone; at other times they expand over the bones, so as to form an entire sheath for the fingers and toes; and are so firmly bound down, that they cannot start from the joints to which they are attached.

The periosteum of the bones is a continued membrane,—each bone is tied to the next by its own periosteum, and betwixt the end of one bone and the beginning of the next, the periosteum is thickened into a strong hard bag, forming a capsule for the joint. The capsule contains a glairy liquor that bedews the heads of the moving bones and prevents friction. There are also strong ligaments or bands, arising from the periosteum, that surround the joints and unite them firmly on every side.

When we cut or injure a tendon, or any part of a joint, the pain at first is very slight; but soon after, when inflammation succeeds, the pain becomes excruciating. Its first action is slow; but when roused, it is obstinate, persevering, and painful. Injury and dislocation of joints are the most acutely agonizing diseases, during inflammatory action, to which the body is subjected. The diseases of joints are almost infinite in variety. Joints are particularly subject to dropsy, gelatinous concretions, inflammation, suppuration, erosion of the cartilages, and exfoliation of the bones. Acute rheumatism is an inflammatory action around the joints, attended with a slight effusion, which is soon absorbed. Chronic rheumatism is a painful and slow inflammation, with gelatinous effusion around the tendons, permanent swelling, and lameness of the affected joint. Gout in a joint is acute inflammation, attended with secretion of earthy matter into its cavity. Inflammation of the tendons is an attendant on sprains. Effusion of gelatinous matter around the tendons forms a ganglion. Suppuration of the tendinous sheath is a whitlow

Inflammation of the bursæ, (or mucous bags,) is a *false* white-swelling, or dropsy of the joint, which, though discharged by repeated punctures, yet in a few hours renews, and requires again to be punctured and discharged. When this species of dropsy in the mucous capsule of a joint happens in a scrofulous individual, it constitutes a *true* whiteswelling. This disease begins with inflammation of the joint, attended by pain, stiffness, and loss of power. These are followed by profuse suppuration, destruction of the cartilages, and spontaneous opening of the joint. Sometimes the disease spontaneously stops, by an effusion of calcareous matter, callus, and concretion of the bones, forming a stiff joint; but more frequently it produces hectic fever and nocturnal sweats, with extreme debility; and the emaciated patient, exhausted with fever, agony, and suffering, and reduced to a skeleton by morbid discharges and colliquative diarrhœa, dies without a struggle.

In our next we shall proceed to describe the muscles of the head and neck.

GEOLOGY.

CHAPTER III.

DESCRIPTION OF THE ELEMENTARY SUBSTANCES WHICH ENTER INTO THE COMPOSITION OF THE EARTH, AND THEIR MORE IMMEDIATE COMPOUNDS.

Material bodies are either simple or compound; that is, they are composed of one ingredient, or more, which no process of analyzation has hitherto been able to decompose. Few of the elementary exist as such, in the natural state. Mineral bodies, whether earthy, alkaline, or metallic, generally exist in combination with oxygen, or some other substance or substances. It is the province of chemistry to separate and recompound natural substances. The mineralogist applies himself to an investigation of their mechanical proporties, as, to form, colour, hardness, opacity, transmission of light, &c. The geologist, on the other hand, considers their nature, in order to determine their origin; he discourses also of their modes of occurrence and distribution.

In giving an account of these, we shall save the reader as much as possible, from all dry unnecessary detail. It is not essential to the study of geology, that the student should be a profound chemist, or mineralogist; but without knowing the general properties and constituents of mineral bodies, he will make little progress in the science: when a small cabinet therefore can be obtained, or where students have the use of a museum, we recommend attention to the form and nature of the principal minerals and rocks, as being, with the aid of books, the best means of enabling him to converse with nature as a geologist, and with the philosopher,

"Exempt from public haunts,
Find tongues in trees, books in the running brooks,
Sermons in stones, and good in everything."

List of elementary substances found in Nature.

1. Elements existing under ordinary pressure and temperature as gases: oxygen, hydrogen, chlorine, fluorine, nitrogen, or azote.

2. Non-metallic liquids and elements; viz., sulphur, phosphorus, selenium, iodine, bromine, boron, carbon.

3. Metalloid bodies which unite with oxygen, to form the earths and alkalies; viz., sodium, potassium, lithium, aluminum, silicum, yttrium, glucinum, thorinum, calcium, magnesium, titanium, strontium, barium.

4. Metals: manganese, zinc, iron, tin, and cadmium, which decompose water at a red heat; and arsenic, antimony, copper, molybdenum, uranium, tellurium, chromium, cerium, nickel, vanadium, cobalt, lead, tungsten, mercury, columbium, bismuth, osmium, silver, palladium, rhodium, platinum, gold, iridium, which do not decompose water.—*Phillips.*

I. *Gaseous Substances.*

Oxygen—so called from its property of forming acids—is one of the most important, and most widely diffused substances in nature. It enters into combination with metallic, and non-metallic bodies, so largely, that it has been computed, that one half of the ponderable matter of the globe is composed of it. Oxygen constitutes about $\frac{1}{20}$th per cent. of the volume of the atmosphere; it forms a third part; by measure of the gases composing pure water, and is locked up to an immense amount in the various rocks, which in fact are little else than a mass of oxidized substances. Plants give out oxygen, and animals absorb it. It has neither taste nor smell, and is a little heavier than the atmospheric air. The following table shows the per centage of oxygen in the earth's minerals and metals, which enter most abundantly into the composition of the crust of the earth:—

Silica = 48·4 silicum + 51·6 oxygen.
Alumina = 53·2 aluminum + 46·8 oxygen.
Magnesia = 61·4 magnesium + 38·6 oxygen.
Lime = 72 calcium + 28 oxygen.
Quartz = 48·4 metallic base + 46 oxygen.
Felspar = 54 metallic base + 44 oxygen.
Mica = 56 metallic base + 46 oxygen.
Granite = 52 metallic base + 48 oxygen.
Basalt = 57 metallic base + 43 oxygen.
Gneiss = 53 metallic base + 47 oxygen.
Clay slate = 54 metallic base + 46 oxygen.
Sandstone = from 49 to 53 metallic base + 47 to 51 oxygen.
Limestone = 52 metallic base + 48 oxygen.*

Hydrogen is the lightest of all known substances, being about thirteen times lighter than the atmosphere. It is combustible, and burns when pure with a yellowish white flame; it is one of the ingredients of water, of which it forms two volumes, and oxygen one. As far as the superficies of our planet is concerned, hydrogen might be supposed to constitute a substance of more relative importance than it really does, in the constitution of the globe. Its occurrence, however, in such large quantities in water, and water in a consolidated state forming no mean ingredient in the general mass of rocky matter, entitles hydrogen to be considered as next in importance to oxygen. It exists in considerable quantities in coal, and is evolved in a compound state from volcanoes and fissures (1) in coal strata.

Chlorine, frequently obtained from the decomposition of muriatic acid, or the spirit of salt, is largely dispersed throughout nature, but always in a state of combination, in sea-water, rock-salt; or that which is procured from brine springs, in which it is united with the metal sodium.

Fluorine enters into the composition of some minerals which form constituent portions of great masses of rocks. Fluoric acid is found in mica and hornblende, two minerals of very great importance, as the component parts of many rocks. From fifteen different analyzations, it has been found that

Mica gives,	1·09	per cent. of	Fluoric acid.
Hornblende,	1·05	do.	do.
Gneiss with Mica,	0·36	do.	do.
Mica slate,	0·54	do.	do.
Hornblende rock and Greenstone,	0·75	do.	do.
Granite with Mica,	0·18	do.	do.
Sienite,	0·65	do.	do.
Fluor-spar,	32·25	do.	do.

Nitrogen constitutes about 80 per cent. of common air. Dr Thomson found it to constitute 15·96 per cent. of the Newcastle caking coal, and it probably exists in rocks which contain the remains of animals. Nitrogen is found abundantly in the waters of some mineral springs. The king's bath, at Bath, evolves 96·5 per cent. of nitrogen, 3·5 of oxygen, and some carbonic acid. The hot well at Bristol evolves 92 per cent. of nitrogen, and 8 of oxygen. The springs at Buxton, Bakewell, and Stony Middletown, Derbyshire, evolve nitrogen only. The specific gravity of nitrogen is, 0·9722.

From the statements given, it is evident that no inconsiderable portion of the mass of the earth consists of substances, which when disengaged and set free, exist at ordinary temperatures in

* See De La Beche on the chemical composition of rocks in his Geological Manual.

Therefore $80+40+24$ contains 8, $10+5+3$ times,
or 144 contains 8, 18 times.

But again, 144 is made up of 100, 40 and 4;

and 100 contains 8, 12 times and 4 over,
40 contains 8, 5 times and 0 over,
4 contains 8, 0 times* and 4 over.

Therefore $100+40+4$ contains 8, $12+5+0$ times and $4+0+4$ over, or 144 contains 8, 17 times and 8 over. But 8 contains 8, 1 time, and therefore 144 contains 17 eights and 1 eight or 18 eights.

The proof that $144 \div 8 = 18$ is that $18 \times 8 = 144$, or that the divisor and quotient multiplied together produce the dividend.

5. In applying this principle to other cases of division, it is not necessary actually to separate the dividend into parts before commencing the process: the same may be done more concisely during the working. To illustrate this, let it be required to divide 11115 by 9. The question is to find a number which multiplied by 9 will give 11115; but that number will be ascertained by finding out how often 9 can be subtracted from 11115. We might therefore proceed to subtract 9 continually, as we did 23 in a former example, until the dividend is exhausted; but it will obviously not affect the result to subtract as many *nines* at a time as we may find convenient, taking care to mark at each step how many are taken away. Now we at once see that 11115 is greater than 1000 times 9; we therefore take away 9000 at once; the quantity 2115 which remains is greater than 200 times 9 (for $9 \times 200 = 1800$, whereas the remainder has 21 hundreds); we therefore take away 1800 leaving a remainder of 315; this remainder again is greater than 30 times $9 = 270$; this number being subtracted, there remains 45 which we know to be just 5 times 9. Therefore 11115 contains 9, $1000+200+30+5$ times, that is 1235 times. The process is shown on the margin above.

11115	
9000	1000 times 9
2115	
1800	200 times 9
315	
270	30 times 9
45	
45	5 times 9
0	

In this operation it will be observed that we really separated the dividend 11115 into parts in finding that

$$11115 = 9000 + 1800 + 270 + 45$$

and had these parts been known to us previous to commencing the operation, we might have proceeded with the division as on the margin.

$$\frac{9000}{9} = 1000$$
$$\frac{1800}{9} = 200$$
$$\frac{270}{9} = 30$$
$$\frac{45}{9} = 5$$
$$\text{Therefore } \frac{11115}{9} = 1235$$

6. From these illustrations it is obvious that the only difficulty which occurs, is in finding out how many times we may subtract the divisor at each step, and this is in a great measure removed by considerations of the following kind:—

21 contains 7, 3 times: therefore
10 times 21 or 210 contains 7, 30 times,
100 times 21 or 2100 contains 7, 300 times,
1000 times 21 or 21000 contains 7, 3000 times,

15 contains 5 more than 2 times; therefore
150 contains 5 more than 20 times,
1500 contains 5 more than 200 times,
15000 contains 5 more than 2000 times;

18	contains	7	more than	2	times, and	less than	3 times,
180	contains	7	more than	20	times, and	less than	30 times,
1800	contains	7	more than	200	times, and	less than	300 times,
18000	contains	7	more than	2000	times, and	less than	3000 times,
180000	contains	7	more than	20000	times, and	less than	30000 times.

To illustrate these principles, let it be required to divide 40761 by 7, that is to find $\frac{40761}{7} = ?$

Here the first figure, 4, of the dividend is less than 7; the quotient sought is therefore less than 10000, for 10000×7 gives 70000, which exceeds 40761. But we observe that 40, the first and second figures together, contains 7 more than 5 times, and less than 6 times; therefore, 40,000 contains 7 more than 5000 times, and less than 6000 times. But 40761 also contains 7 more than 5000 times, for 40761 is greater than 40000; it also contains 7 less than 6000 times, because 6000 times 7 is 42000, a greater number than 40761. We may therefore subtract 5000 times $7 = 35000$ from 40761, which leaves a remainder of 5761. The quotient sought is therefore $5000 + \frac{5761}{7}$. It remains now to find how many times 5761 contains 7. Proceeding as before, we observe that 5 does not contain 7, but that 57 does contain it more than 8 times, and less than 9 times; therefore, 5700 contains it more than 800 times, and less than 900 times; as does 5761; subtracting the 800 times 7, or 5600, there remains 161. The quotient is therefore $5000 + 800 + \frac{161}{7}$. Now, 16 contains 7 more than 2 times, and less than three times; therefore, 160 contains 7 more than 20 times, and less than 30 times; as does also 161; subtracting then 20 times 7, or 140, there remains 21. Now, 21 contains 7 just 3 times; and this being subtracted, the dividend is exhausted. We therefore conclude that

40761	
$35000 =$	5000 times 7
5761	
$5600 =$	800 times 7
161	
$140 =$	20 times 7
21	
$21 =$	3 times 7
0	
$40761 =$	5823 times 7

$$\frac{40761}{7} = 5000 + 800 + 20 + 3 = 5823.$$

The following examples may be gone over in the same manner:—

$$\frac{1656}{3} = 552 \qquad \frac{8765}{5} = 1753 \qquad \frac{97587}{7} = 13941$$

7. The same method illustrated above is applicable however great is the divisor. One other example will make this plain: let it be the following—Divide 4298689 by 576.

We here observe, that it takes the four figures on the left of the dividend, namely, 4298, to make a number which is greater than 576, the divisor: the dividend is therefore separated into 4298000 and 689. Now, 4298 is found to contain 576 more than 7 times, and less than 8 times; therefore 4298000 contains it more than 7000 times, and less than 8000 times; and subtracting 576×7000 from the dividend, the remainder is 266689. The four figures, namely 2666, on the left of this remainder, contain 576 more than 4 times, and less than 5 times, therefore the whole remainder contains it more than 400 times, and less than 500 times; and 576×400 being subtracted, there arises the new remainder. With this the same operation is repeated until it appears that the quotient is

4298689	
$4032000 =$	7000 times 576
266689	
$230400 =$	400 times 576
36289	
$34560 =$	60 times 576
1729	
$1728 =$	3 times 576
1 *remainder.*	

$$7000 + 400 + 60 + 3 \text{ and 1 over.}$$

8. It will be observed in examining the foregoing examples, 1st. That it is unnecessary to write the ciphers which are placed on the right of each subtrahend, provided we take care to keep the significant figures in their proper places without them. 2d. That it is unnecessary to put down those figures of the dividend which fall over ciphers as they do not begin to be of use in forming the quotient until significant figures fall under them; and 3d. That the figures of the quotient might be written in succession in the usual way. The last example is shown in this abridged form at the side, and it is particularly to be remarked: 1st.

Divisor Dividend Quotient.
576)4298689(7463
4032
2666
2304
3628
3456
1729
1728
1

* We use this form of expression for convenience. We ought to say that 4 *does not contain* 8, but the expression 0 times is equally intelligible, and is therefore preferable on the score of uniformity.

That one figure of the given dividend appears on the right of every partial dividend. 2d. *That for every figure of the dividend not employed in the first partial division, there is a quotient figure of the same order.*

9. From the nature of the numeration scale, it is obvious that no partial quotient can exceed 9, which is the highest number of only one figure: should a partial product come out 10 or more, there is an error in the preceding step.

10. From the foregoing principles, the following rule for division is deduced:—

I. *Write the divisor and dividend in one line, and place reversed parentheses on each side of the dividend.*

II. *Cut off from the left of the dividend, the smallest number of figures which make a number as great or greater than the divisor; find what number of times the divisor is contained in these, and write the figure which results as the first figure of the quotient.*

III. *Multiply the divisor by the quotient figure, and subtract the product from the number which was cut off as a partial dividend, from the left of the given dividend. (If the product cannot be subtracted, that is, if it is greater than the part of the dividend cut off, the figure placed in the quotient is too great, and a less figure must be taken. On the other hand, if after the subtraction, the remainder be greater than the divisor, the quotient figure has been taken too small, and a greater one must be taken.)*

IV. *On the right of the remainder place the figure of the dividend which comes next after those at first taken in* II.: *find how often this number contains the divisor, and place the resulting figure on the right of the first figure of the quotient: multiply the divisor by it, and subtract the product which results from the partial dividend. (Should it happen at any time that the remainder, increased by the figure of the dividend taken down, is less than the divisor, a 0 must be placed in the quotient, and another figure of the dividend brought down; and this must be repeated, if necessary, until the augmented remainder is capable of containing the divisor, or the figures of the dividend are exhausted.)*

V. *Proceed with all subsequent partial dividends as directed in* IV., *continuing the process till all the figures of the dividend are brought down.*

The following example illustrates this rule:—

```
Divisor. Dividend. Quotient.
  251 )577556( 2301
       502
       ---
        755
        753
        ---
          256
          251
          ---
Remainder   5

Proof.
  2301 Quotient.
   251 Divisor.
  ----
  2301
 11505
 4602
         5 Remainder.
 ------
 577556 Dividend.
```

Here we take the first three figures on the left of the dividend, as the first partial dividend, and dividing by the divisor, we write in the quotient the number 2, resulting from the division, and multiply the divisor by this number. We write the product 502 under the partial dividend 577. The subtraction being performed, we bring down the 5 hundreds of the dividend, and annex the figure to 75, the remainder. We divide this new partial dividend by the divisor, and obtain 3 as the second figure of the quotient; we multiply the divisor by this number, and subtract the product 753. To the remainder, 2, we annex 5, the tens' figure of the dividend, making a partial dividend 25. But as this does not contain the divisor, (or, as we say for the sake of uniformity of expression, as 25 *contains* 251, 0 *times*,) we write 0 for the next figure of the quotient, and bring down 6, the units' figure of the dividend, making the partial dividend 256. This containing the divisor *once*, we therefore write 1 in the units' place of the quotient, and subtract the divisor, that is, $251 \times 1 = 251$, from the partial dividend 256; this gives a remainder 5.

$$\text{Therefore } 577556 = 251 \times 2301 + 5.$$

When the divisor contains several figures, as in the foregoing example, some difficulty may be felt in discovering how often it is contained in the partial dividend. Although nothing but practice can enable us to do this with facility—for with every one it is a sort of guess-work—yet the difficulty is not in reality so great as it in general appears to the beginner. We take the following example to show how it is accomplished—Divide 423405 by 485.

```
485 )423405( 873
     3880
     ----
      3540
      3395
      ----
       1455
       1455
       ----
          0
```

Taking the four figures on the left of the dividend to form a number capable of containing the divisor, we do not see immediately how often 4234 may contain 485. To aid us in guessing, we observe that 485 is between 400 and 500, and that if it were either the one or the other of these numbers, the question would be reduced to finding how often 4 or 5 is contained in 42. The reason is, that 4 or 5 being contained in 42 as often as 400 or 500 is in 4200, and this last differs little from 4234. We see at once, then, that our quotient figure cannot be greater than 10, nor less than 8: it cannot be so great as 10; for on that supposition, the three figures on the left of the dividend would contain the divisor *once*, which they do not. It only remains, then, to try whether 9 or 8, employed as a multiplier of 485, yields a product which can be subtracted from 4234, and we find that it is 8; 8, therefore, is the first figure of the quotient. When $485 \times 8 = 3880$ is subtracted, and the next figure (0) of the dividend annexed, we find the second partial dividend to be 3540. Reasoning upon our divisor as before, we observe that the next quotient figure cannot be greater than 8, nor less than 7; but as 485 is nearer to 500 than to 400, we try 7, which results from a division of 35 by 7; the supposition turns out to be correct; for $485 \times 7 = 3395$, and this subtracted from 3540, leaves 145, which is less than the divisor. By annexing 5 to 145, we get 1455, our third partial dividend, and as 1455 approaches to 15,00, and 485 to 5,00, we try 3 for our next quotient figure, and find that $485 \times 3 = 1455$.

It would now be highly advantageous to repeat the foregoing three articles, with the following examples:—

$$\frac{3978}{17} = 234 \qquad \frac{6331}{21} = 301 \qquad \frac{197028}{234} = 842$$

Prove that $224091 = 4309 \times 52 + 23$.

Also, that $\frac{224091 - 23}{2} = 4309 \times 26$.

Is $215414 = 1781 \times 121 + 13$?

ANATOMY AND PHYSIOLOGY.

CHAPTER IV.

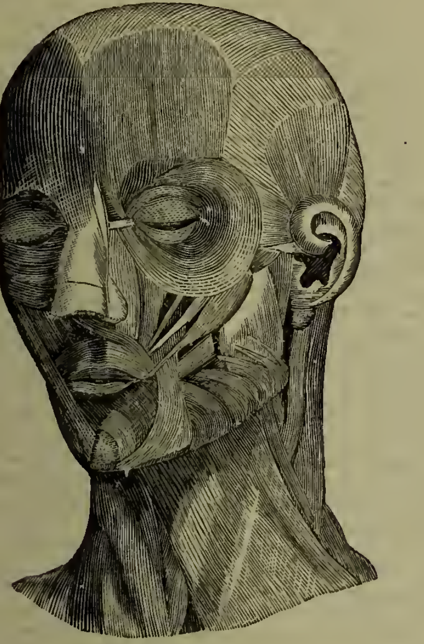
THE MUSCLES AND MUSCULAR ACTION.

There are about 450 muscles in the human subject, 225 on each side, with a small numerical difference in the male and female. In describing the muscles, I will give each its anatomical name, for it is not possible to do justice to the subject without it. The description will, in general, not be so minute as to fatigue the reader's mind, and the whole will be separated into natural divisions. The skin is supposed to be dissected from the accompanying figure exhibiting the principal muscles of the face.

There are four muscles in the face; 1st, The occipito frontalis covers the upper part of the cranium, or skull, corrugates the hairy scalp, and wrinkles the forehead when we express passion. 2d, Corrugator supercilii forms part of the eyebrow, and wrinkles it when we frown. 3d, Orbicularis oculi covers and surrounds the eyelids, presses the eyeball firmly into the socket, and squeezes the tears from the lachrymal gland. 4th, Levator palpebræ superioris spreads over the upper eyelid, and forms it. When elevated the eye is open, when depressed it is shut, and when paralyzed it is closed.

There are twelve muscles in the nose and mouth. 1st. The levator labii superioris and alæ nasi, extends along the nostrils, raises the upper lip, and widens the nostrils, especially

when we are enraged, or spasmodically cough, as we do in asthma. 2d. Levator labii superioris proprius forms part of the



cheek and upper lip, and pulls the upper lip and septum of the nose directly upwards. 3d. Levator anguli oris forms part of the angle of the mouth, and raises it upward. 4th. Zigomaticus major forms part of the cheek, the corner and circle of the mouth, and depresses the lip. 5th. Zigomaticus minor has its origin, insertion, and action, nearly the same as the zigomaticus major. These zigomatic muscles mark the face with the line (which extends so visibly in some individuals,) from the cheek-bone to the corner of the mouth, and pull the angles of the mouth upward, when we laugh, rage, or grin. In negroes, there are frequently three zigomatic muscles, but only two in Europeans. 6th. Buccinator assists in forming the walls of the cheek, flattens the cheek, assists us in swallowing liquids, and in turning the morsel we are chewing in our mouths, and likewise prevents it getting betwixt our teeth; and when we blow wind instruments, these muscles dilate like a bag, and, contracting upon the wind in the mouth, expel it, and swell the notes. 7th. Depressor anguli oris forms part of the flesh of the lower jaw and corner of the mouth, gives form to the chin and mouth, and expresses laughing, smiling, and other cheerful passions. It also assists in pulling the corner of the mouth downward, especially when we express the malignant passions of hatred, contempt, and revenge. 8th. Depressor labii inferioris lies on the sides of the chin, and pulls the lip downward. 9th. Orbicularis oris lies in the red part of the lips, surrounds the mouth, contracts and shuts it. 10th. Depressor labii superioris, and alæ nasi, arises from the socket of the fore teeth, goes into the root of the nostril, and pulls the nose and upper lip downward. 11th. Constrictor nasi lies on the side of the nose, goes to its very point, and compresses it. 12th. Levator menti arises at the root of the incisor teeth, spreads on the centre of the chin, contracts it, and forms the dimple.

The muscles of the nose and mouth are not only useful to express our passions, but also assist us in performing the more important functions of breathing, speaking, chewing, swallowing, &c., and opening and shutting the mouth. Partial paralysis of these muscles induces a frightful distortion of the countenance. If one side of the face only is paralyzed, the palsied muscles of the affected side cease to act, and the sound ones on the healthy side still exerting their usual vigour, pull the palsied muscles toward the unparalyzed side, and distort the face.

In some individuals, when the facial muscles and passions are at rest, their countenances indicate nothing but muscular harmony; but whenever they smile, laugh, grin, or exhibit anger, their mouths and faces are instantly drawn to one side, and remain in that state till the paroxysm is over. This is caused by a chronic paralysis of some of the muscles on one side of the face having reduced their power, and made it unequal to their antagonists of the opposite side.

On the external ear there are eight muscles. 1st. Superior auris, expands on the fascia of the temporal muscle behind the ear, terminates in the antihelix, (or inner ring of the ear,) posteriorly, and lifts the ear upward. 2d. Anterior auris, arises from the zigoma, (or arch of the cheek,) and passes into the helix, or outward ring of the ear. 3d. Posterior auris, arises from the mastoid process of the temporal bone on the side of the head, and is inserted into the back part of the concha, or shell of the ear. 4th. Helicis major, lies on the sharp point of the helix, or outward ring of the ear, and is inserted a little above the tragus, or the outward cartilage, or grisly substance of the ear. 5th. Helicis minor, lies a little lower on the ear than the helicis major. 6th. Tragicus, and 7th. Antitragicus, lie contiguous to each other, on the ear, anteriorly, almost in juxtaposition. 8th. Transversus auris, runs on the back part of the ear, from the shell to the inner ring.

There are still a few smaller muscles, which also belong to the ear, move and give tension to its external cartilages, and prepare it for receiving and propagating the vibrations of air and sound along its tube. These I will not here describe nor enumerate, because they are too minute for the general student to perceive, unless by actual dissection.

The muscles of the eyeball are six in number. 1st. Rectus superior, lifts the eye directly upward, and expresses its haughtiness and pride. 2d. Rectus inferior, pulls the eye downward, expressing modesty and humility. 3d. Rectus internus, carries the eye inward, towards the nose. 4th. Rectus externus, turns the eye away, expressing anger and scorn. 5th. Obliquus superior, (like the recti superior and inferior,) arises in the bottom of the eye, above, towards the inner side, directing its long smooth tendon to the internal angle of the eye, and there it passes through a cartilaginous pulley, placed above the eye, and projecting farther than the most prominent part of the eyeball. The tendinous cord then returns at an acute angle, and bends its centre downward before it can touch the eyeball; it then returns backward in a direction opposite the recti muscles, slips under the body of the rectus superior, and spreads under it, and upon, or behind the middle of the eye, about half-way betwixt the insertion of the rectus superior and the entrance of the optic nerve into the eyeball. 6th. Obliquus inferior, is directly opposed to the obliquus superior in form, place, and office: it is a short, flat, broad muscle, arising from the orbitary process of the superior maxillary or cheekbone, near its union with the os unguis (or eyebone,) and is inserted and expanded on the eyeball, exactly opposite the insertion of the obliquus superior. These two last named muscles, (obliqui superior and inferior,) support the eyeball for the operation of the recti muscles; for when the oblique muscles act, and pull the eye forward, the recti muscles resist them, and the insertion of the oblique muscles at the middle of the eyeball becomes, at that instant, a fixed point or axis, round which the eyeball turns, under the operation of the recti muscles. The conjoined action of the oblique muscles brings the eyeball forward from the socket. The superior oblique muscle, acting alone, does not bring forward the eye, but rolls it so as to turn the pupil downward and towards the nose. The single action of the obliquus inferior is the reverse, for it returns the eye again upon its axis, and directs the pupil upward and outward.

But it may be necessary to enter a little more minutely into the mechanism and physiology of the recti muscles of the eye, collectively and individually, to make the reader more easily comprehend their harmony and usefulness, in making us accomplish a mechanically correct vision, and see objects as they are distinctly. The four recti muscles, superior, inferior, internus, and externus, arise by flat, small tendons, round the margin of the optic foramen, (or hole,) at the bottom of the socket, and are placed, one above, one below, and one on either side, and completely surround and adhere to the optic nerve; they then gradually expand upward, and with their fleshy bellies surround and cover the middle of the ball of the eye, and still expanding and extending upward, each at last terminates in a broad, flat, white tendon, covering all the fore part of the eyeball up to the

very circle of the lucid cornea, (or window of the eye,) and these very white and shining tendons anteriorly, form what is called the white of the eye. The rectus externus, is the muscle nearest the temple, and is a little longer than the rectus internus nearest the nose. The rectus superior, is above, the rectus inferior, below, and are both of equal length. The eye is thus entirely surrounded with its muscles, which turn and move it mechanically in all directions, either for looking accurately at small, large, near, and distant objects, or expressing the emotions and passions of the mind.

Strabismus, or squinting, is caused by one or more of the muscles of the eye being shortened or elongated; and by the derangement of their action, the pupil is consequently carried out of the proper axis of vision. It is cured by a very simple operation. The shortened or elongated muscle is cut down upon and divided by a skilful operator. The false position of the pupil is immediately rectified by the division of the diseased muscle, that induced obliquity by its irregular action. Inflammation is subsequently prevented, or removed, by proper applications. The divided muscle in healing shortens, or lengthens; and during the healing process, suits itself to the exigences of the case, and in a short time reunites. All the muscles of the eye now act in harmony, and the squinting is radically removed. No person need submit for any length of time to obliquity of vision, so long as he can be effectually cured by submitting to this simple, and not very dangerous operation. But like other surgical operations it is sometimes unsuccessful; and a case lately happened, in which, after the operation by a surgeon, the patient was rendered blind of the defective eye.

There are four muscles in the lower jaw. 1st. The temporal, arises from the flat side of the parietal bone at the side of the head, and the sphenoid and frontal bones in that hollow, behind the eye, where they meet to form the squamous suture; it also arises from the inner surface of that strong tendinous membrane, which is extended from the jugum, or yoke, to the semicircular ridge of the parietal bone, at the side of the head. The muscle is pyramidal, its rays converge towards the jugum, its tendon passes under it, and is inserted into the coronoid process of the lower jaw. It pulls the lower jaw firmly up, and when we bite, it swells on the flat part of the temple, so as to be felt outwardly. 2d. The masseter, a short, thick, fleshy muscle, which gives the visible rounding to the cheek, arises from the upper jawbone, and covers the branch of the lower jaw, quite down to its angle, where it is inserted. The parotid gland lies on its upper portion, and the duct of the gland, crossing the cheek, lies over the muscle. It pulls up the jaw, and when we bite, it is felt swelling on the back part of the cheek. 3d. Pterygoideus internus, arises from the internal flat pterygoid process of the sphenoid bone, and goes inwardly to the angle of the lower jaw. 4th. Pterygoideus externus, arises from the outside of the external plate of the pterygoid process of the sphenoid bone, and the adjoining part of the upper maxillary or cheekbone, and is inserted into the neck of the condyle of the lower jaw, and to the upright part of the bone and capsule of its joint. The lower jaw is chiefly moved by these four muscles. The temporal muscle acts on the coronoid process of the lower jawbone like a lever, and raises it. The masseter muscle acts before the temporal muscle on the angle of the lower jaw, and lifts it. The pterygoideus internus acting within the lower jawbone balances the action of the masseter on the outside. In biting, holding, and tearing our food with our teeth, these three muscles pull the lower jaw very forcibly upward. The fourth muscle, or pterygoideus externus, going from within, outward from its origin to its insertion, naturally pulls the lower jaw from side to side in chewing, and performs the motion of grinding the food.

There are two muscles that lie on the fore part of the neck and move the head. 1st. Platysma myoides, a very thin muscular expansion, spreading over the other muscles of the neck and throat, and extending upward on the lower part of the face and lower jaw. It supports the parts of the neck, compresses the veins, and, in difficult breathing, forces the blood down into the chest. It is more a muscle of respiration and circulation than of mental expression; yet in some of the most violent passions, it is very active and effective in their malignant exhibition. 2d. Mastoideus is the finest and most conspicuous muscle of the body, giving the fleshy roundness to the neck, and rising up when in action, it produces the most beautiful contour in the necks of men and women. It begins by a strong tendon from the triangular position of the sternum, or breast-bone, and from the sternal portion of the clavicle (or collar bone,) by a broad and fleshy origin, and is inserted into the mastoid angle of the temporal bone, at the side of the head. When the mastoid muscles act in unity on both sides of the head, they pull the head downward, and bring the chin in contact with the chest. When one only acts on one side of the head, it pulls the ear down to the shoulder, and by twisting the neck, throws the chin a little up to one side. This muscle is subject to the disease which sometimes produces a wry neck; and it requires a correct knowledge of anatomy, in some cases, to discover whether the distorted neck arises from disease or palsy of the mastoid muscle, or an affection of the spine.

Before describing any more of the muscles, I will briefly enumerate the bones and cartilages that form the basis of the throat and tongue, and are the centre of their motions. 1st. Os hyoides is a small bone (resembling the lower jawbone), that forms by its basis the root of the tongue, and is sometimes called the bone of the tongue. Its horns keep the gullet and windpipe extended, and it is the centre of the motions of the tongue and muscles of the throat. The trachea, (or windpipe,) conveys the air to the lungs. The larynx is the head (or figured part) of the air-tube which is formed like a flute, for the modulation of the voice, and is composed of several cartilages, or grisly rings, that it may stand firm and uncompressed; were it otherwise, the windpipe would be liable to collapse, and induce suffocation. It has five principal cartilages:—1st. The thyroid cartilage, makes that prominence on the middle of the throat called pomum Adami, or apple of Adam. Its two long horns at its upper corners rise like hooks above the line of the cartilage, and are joined to the horns of the os hyoides, or bone of the tongue. 2d. The cricoid cartilage lies next the thyroid, and below it; and on its back, or deeper part, internally, are seated two small cartilages, which, with their ligaments, form the opening of the windpipe, for the admission of air into the lungs. 3d. and 4th. The arytenoid cartilages are two in number, and seated within for protection of the thyroid cartilage, and are covered with the common membrane of the throat, which is thick and full of mucous glands; and betwixt these ligaments, the rima glottides, or chink, is formed for opening a passage into the tube of the trachea, or windpipe. The voice is in a considerable degree formed by the motion of these cartilages with their ligaments; and the action of their muscles is so exquisitely minute, that for every change of tone, and there are thousands of changes in the human voice, they move in a proportionally minute degree to effect it. 5th. The epiglottis is fixed to the thyroid cartilage, the bone and root of the tongue, and in action executes the part of a key to a wind instrument. It defends and shuts the rima glottides, or opening into the windpipe, especially when we swallow food or liquids, and by covering the opening, prevents the smallest morsel or drop from entering the windpipe; for a morsel passing into the windpipe would cause instant suffocation and death. The rareness of such accidents indicates its perfect mechanism and utility, and causes us to admire the infinite wisdom and skill of our almighty Creator and Preserver.

In my next essay I will proceed with the muscles.

GEOLOGY.

CHAPTER IV.

DESCRIPTION OF THE ELEMENTARY SUBSTANCES WHICH ENTER INTO THE COMPOSITION OF THE EARTH, AND THEIR MORE IMMEDIATE COMPOUNDS.

IV. *Metals.*

Manganese forms a constituent of many minerals. The black oxide is found native in great abundance. The native peroxide occurs crystallized and compact in Devonshire, Somersetshire, and in Aberdeenshire. The crystals often occur with the sulphate of barytes and are found radiated in rhomboidal dark-grey coloured prisms. Oxide of manganese occurs principally in primary and transition rocks in nodules or irregular masses, in veins

Common Process.	Abridged Process.
30400000) 16014387161 (526	304) 160143 (526
152000000	1520
81438716	814
60800000	608
206387161	2063
182400000	1824
23987161	23987161

To divide by 5, multiply by 2, and strike off the last figure, half of which is the remainder, and what precedes is the quotient.

For $2150 \div 5 = (2150 \times 2) \div (5 \times 2) = 4300 \div 10 = 430$.

Reciprocally, the easiest way of multiplying by 5, is to annex a cipher and to divide by 2.

To divide by 25, multiply by 4, and strike off the last two figures, which leaves the quotient; and a fourth part of the figures struck off, considered as one number, is the remainder.

For $1725 \div 25 = (1725 \times 4) \div (25 \times 4) = 6900 \div 100 = 69$.

Reciprocally, to multiply by 25, annex two ciphers, and divide by 4.

As multiplication and division are exactly inverse operations, it is unnecessary to prescribe any other mode of forming exercises in this rule; for the division of one number by another being effected, the correctness or incorrectness of the result is at once proved by multiplying the quotient by the divisor, and adding the remainder if any; this final result ought to be the dividend. As this however is like working without an object, the student may prove for himself that the following formulæ are true, whatever numbers we put for A and B, (provided always that A be made greater than B.)

$$\frac{A \times A - B \times B}{A - B} = A + B \qquad \frac{A \times A + 2 \times A \times B + B \times B}{A + B} = A + B$$

Thus supposing $A = 169$ and $B = 37$; the formulæ assert that

$$\frac{169 \times 169 - 37 \times 37}{169 - 37} = 169 + 37 = 206$$

$$\frac{169 \times 169 + 2 \times 169 \times 37 + 37 \times 37}{169 + 37} = 169 + 37 = 206.$$

Question. Suppose there are one thousand millions, six thousand five hundred and sixty human beings in the world, and that the average of life is 36 years of 365 days; how many die every day? *Ans.* 76104.

ANATOMY AND PHYSIOLOGY.

CHAPTER V.

THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

Every motion of the body is performed by its muscles,—they move us from one place to another; and without them we could not enjoy the pleasures of locomotion. Birds fly, fishes swim, insects run, and reptiles creep by muscular power. I lay down my arm by a layer of muscles placed below it for this purpose. I raise it by another layer placed above it. Into whatever position I put my body, turn, and twist it, the movements are not only muscular, but more mechanically just, than the motions of the nicest adjusted machinery of a patent-chronometer, or the correctly arranged apparatus of the best high-pressure engine. If I speak, sing, or whisper, the muscles of my windpipe, and tongue, minutely contract in almost an infinity of movements without my consciousness, and produce the sounds required, according to the exactest laws of oral expression, and musical harmony. The tongue and its motions are muscular. The eyeballs are mechanically moved and adapted to the laws of optics by their muscles. The collection and communication of the vibrations of air by the external ear, and the motions of the little bones of the internal ear, by which sounds are conveyed to the auditory nerve and brain, are the result of the most beautifully correct and harmonious muscular action. The peristaltic motion of the bowels is muscular. Eating, swallowing, ejecting, and dejecting, are simply the result of muscular power. Without the muscles, man would be a mere automaton, having the external human form without the faculty of locomotion, and lie inactive in whatever position he was placed, like a fallen statue, exposed to the winter storm and the summer sun, without the means of defence, and perish in utter helplessness by the inclemency of the seasons, of nakedness, hunger, and thirst. If man were not endowed with muscular power, he would naturally fall forward; and, according to the laws of gravity, he could not stand erect. It is muscular power that not only preserves his upright position, but makes him move slowly, rapidly, gracefully, and slovenly as he feels inclined. The mechanism and adaptation of the muscles is based, like other mechanical action, on lever power—a convincing proof that our Almighty Creator is not only infinitely wise and provident, but has made and adapted them according to the most perfect mechanical laws. Muscles are composed of fibrin, albumen, gelatine, extractive phosphate of soda, phosphate of ammonia, phosphate of lime, and carbonate of lime. Their atomical composition, by bulk, is one atom of oxygen, and three atoms of hydrogen.

To prevent any misapprehension among readers, I may simply mention, that by the muscles—I mean those parts of the body commonly known by the name of lean flesh. In my last essay I described the mechanism and functions of the muscles of the head, and also the cartilages of the windpipe. In my present essay, I will begin where I terminated in my last. The subject cannot fail to be interesting to mechanics and students, and indeed to every person who wishes to understand the structure and functions of his own body. The individual who is ignorant of this knowledge, notwithstanding all his other acquirements, is destitute of the first and best elements of domestic, social, and philosophical education. I feel sorry that I am obliged to give so many of the semi-barbarous old anatomical names of the muscles in describing their mechanism and action, for they are not known by any other nomenclature. The origin of these obsolete names is generally derived from the Greek; and if properly understood, they are intended to express their appearances, shape, situation, uses, and action. But why they should always remain in this Greekish jargon, is an anomaly I cannot explain, otherwise than for the sake of making them harmonize with the enigmatical Latin prescriptions, affected pomposity, assumed gravity, and mysterious taciturnity of the dignified medical profession, that in many instances (so unchangeable are its manners), for the last two hundred years, has not made one decided attempt at a rational reform. In these untoward circumstances, it might be deemed presumptuous, were I to attempt to change, in this Journal, the anatomical nomenclature which has been so gravely sanctioned by so many learned anatomists and great public teachers in ancient and modern times. But notwithstanding all this conservatism, there have, nevertheless, been many important suggestions and practical hints devised for its reformation, by some of the most celebrated private anatomical lecturers of the age. Dr. Robert Hunter, the eminent professor of surgery in the Andersonian University, Glasgow, proposed, in a medical periodical, as an improvement, to describe the muscles simply by *enumeration*, and gave us some examples of the facility and utility of his plan; but as it was not generally appreciated by our celebrated public anatomists, who claim the privilege of being the legitimate leaders of professional fashions, it fell to the ground in embryo, like many other great abortions of ingenious minds.

As the technicalities of anatomy make learned treatises on this subject sealed books to the masses—for the use of mankind they ought to be simplified.

There are three muscles on the throat which pull it downward; 1st, The sterno-hyoideus, a broad flat riband-like muscle, passing from the sternum (or breast bone), to the os hyoides (or bone of the tongue). It pulls the throat directly downward. 2d, The sterno-thyroideus, a flat, smooth, riband-like muscle, thicker and fleshier than the former, and very uniform in bulk, passes

from the sternum to the thyroid cartilage, and pulls the throat downward. 3d, The omo-hyoideus, a long, slender muscle, reaches from the shoulder to the os-hyoides. If this muscle acts singly, it pulls the throat to one side; if both act, one on each side, their power is equally balanced, and they assist the two former in pulling the throat directly downward, and at the same time it presses the windpipe a little downward and backward. These three muscles are almost continually in action, and are only completely relaxed when we are eating,—their relaxation permits the throat to be drawn upward, and the mouth thrust a little backward, which always happens during deglutition, which cannot be performed otherwise.

There are four muscles on the neck that pull the throat upward. 1st, The mylo-hyoideus, a flat broad muscle (arising from the whole semicircle of the lower jaw), divided by a tendinous white substance down its middle, in a line with the chin, and inserted at the base of the os-hyoides at the root of the tongue. Some anatomists divide this muscle into two, and call them distinct muscles. 2d, Genio-hyoideus, a neat pair of muscles, beautiful and radiated, arising from a small tubercle behind the chin, implanted into the basis of the os-hyoides. The sub-maxillary gland lies between this muscle and the omo-hyoideus, and in the middle, the duct of the gland pierces the membrane of the mouth, to open beneath the root of the tongue. The mylo-hyoideus, and genio-hyoideus, move the bone of the tongue forward and upward, when the lower jaw is fixed; but when the os-hyoides is fixed by the muscles that come from the sternum or breast bone, they pull the jaw downward. 3d, The stylo-hyoideus is one of three beautiful slender muscles, arising from about the middle of the styloid process, and is fixed into the side of the os-hyoides. Its fibres split above its insertion, and form a neat small loop for the passage of the tendon of the digastric muscle. The one of the other two-styloid muscles is inserted into the pharynx, and the other into the tongue; their common action is to draw back the tongue, and pull up the throat. 4th, The digastricus, is a double-bellied muscle; the one belly arises from the root of the mastoid process, and, proceeding obliquely forward and downward, passes by the side of the os-hyoides, slips through the loop of the stylo-hyoideus, and is fixed by a tendinous bridle to the side of the os-hyoides; and then, turning upward towards the chin, ends in a second fleshy belly, which is inserted into the lower jaw on the inside of its circle. This muscle, along with the stylo-hyoideus, pulls the throat upward and backward.

There are seven muscles on the throat that move the parts and the cartilages of the windpipe upon each other.

1st, The hyo-thyroideus goes from the thyroid cartilage to the os-hyoides, and compresses and shortens the windpipe. 2d, The crico-thyroideus, passes from the upper edge of the cricoid, to the lower margin of the thyroid cartilage, and also compresses and shortens the windpipe. 3d, Musculus arytenoideus transversus, arises from almost the whole length of one of the arytenoid cartilages, and is inserted to the same extent into the other. It contracts the glottis by drawing the cartilages towards each other. 4th, Arytenoideus obliquus, arises from the root of one arytenoid cartilage, goes obliquely into the other, draws them together, and closes the rima glottidis. 5th, Crico-arytenoideus-posticus, a small pyramidal muscle arising from the back part of the cricoid, is inserted into the posterior portion of the thyroid cartilage. It pulls the arytenoid cartilages directly backward, lengthens the slit of the glottis, and by closing it neatly, produces some of the most delicate modulations of the voice. 6th, Crico arytenoideus lateralis, comes from the sides of the cricoid, and is implanted into the arytenoid cartilage. It pulls them asunder, and slackens the lips of the rima glottidis, or opening of the windpipe. 7th, The thyreo-arytenoideus, arises from the posterior surface of the wing of the thyroid, and is implanted into the anterior part of the arytenoid cartilage. It pulls them forward and sideways, slackens the ligaments, and widens the glottis.

There is yet another muscle, the thyreo-epiglottideus, which has been divided by Albinus into major and minor; but it is frequently wanting. There are also a set of fibres, sometimes seen running from the arytenoid cartilage to the epiglottis, called the aryteno-epiglottideus, but in many subjects they are also not present. When the masticated morsel in the mouth, after being chewed, is prepared to be swallowed, the velum palati (or curtain of the palate), depending at the posterior part of the mouth, is drawn upward, and the opening of the throat is expanded. But whenever the morsel has passed down into the œsophagus or gullet, the curtain of the palate again falls down; for when the arch of the throat is contracted, and the gullet is compressed by its own muscles, the food is then forced downward into the stomach, more by muscular action than its own gravity. Indeed, the muscles of the throat can perform this function very easily against the laws of gravity altogether; for sometimes we see showmen and mountebanks with facility swallowing food and liquids, while standing erect on their heads, with their feet uppermost, merely to elicit money and applause from their spectators.

There are eleven muscles belonging to the palate and pharynx, which I will now briefly describe. 1st, Azygos uvulæ, in the centre of the velum pendulum palati, or that curtain which hangs at the back of the throat. There is a small depending pap or point of flesh called the pap of the throat. The azygos uvulæ is the only muscle belonging to this pap, and pulls it upward to keep it out of the way of the morsel about to be swallowed after mastication. 2d, Levator palati mollis arises from the os-petrosum, the Eustachian tube, and sphenoid bone, and spreads over the velum pendulum palati, or curtain of the throat. It pulls up the curtain when food is to be swallowed, and also prevents the food from passing up to the nostrils by spreading the velum or curtain backward, and protecting the passage. It also protects the mouth of the Eustachian tube, or internal opening of the ear, and prevents the food passing into it, so that hearing is unimpaired. 3d, Circumflexus palati arises from the sphenoid bone, and the beginning of the Eustachian tube, or internal opening of the ear at the back part of the mouth: it runs along the tube, and becoming tendinous, turns under the hook of the internal pterygoid process, and mounts again to the side of the curtain of the palate: its office is to pull down the palate, and by stretching it to make it tense. 4th, Constrictor isthmi faucium arises from the root of the tongue on each side, extends to the middle of the velum (or curtain), and terminates near the uvula. The semi-circle which this expansion describes forms the first arch that presents itself to the eye, when we look into the mouth. This muscle pulls down the curtain and elevates the root of the tongue, to meet the vail. 5th, Palato pharyngeus, forms the second arch of the throat, begins at the middle of the soft palate, extends round the entry into the fauces, and terminates in the wing or edge of the thyroid cartilage. The first arch belongs to the root of the tongue; the second arch belongs to the gullet. This muscle contracts the arch of the fauces, or gullet, and assists in closing it on the food passing down the œsophagus, on its way to the stomach.

I will now explain the pharynx. The pharynx is that opening of the gullet which hangs from the basis of the skull, and is attached to the occiput, or posterior bone of the head, also to the pterygoid process, and the back parts of the jaw-bones. It expands into a large capacious bag, for the free reception of the morsel of food about to be swallowed, and terminates in the œsophagus, or that tube by which the food is conveyed down into the stomach. The pharynx is bounded by the root of the tongue, and the arches of the throat. It lies flat and smooth posteriorly, along the bones of the vertebræ, or spine, over which it is placed. It is protected anteriorly, and partly surrounded by the cartilages of the wind-pipe. Its sides are embraced by the horns of the os-hyoides, or bone of the tongue, and it is covered with flat muscular fibres, arising from this bone and the cartilages. These fibres spreading round the pharynx are named its constrictors, because they embrace it closely, and force down the masticated food by their contractions. 6th, The stylo-pharyngeus (a long slender beautiful muscle) arises from the root of the styloid process, expands on the side of the pharynx, and extends to the edge of the thyroid cartilage. It raises the pharynx to receive the morsel, and then straightens and compresses it to push the morsel down, and by its hold on the thyroid cartilage, it commands not only the larynx, but the whole of the throat. 7th, Constrictor-superior, arises from the basis of the skull, the jaws, palate, and root of the tongue. It surrounds the upper portion of the pharynx, and is not one circular muscle, but rather two muscles divided in the middle, posteriorly, by a distinct rapha, or approximation of opposite fibres. 8th, Constrictor medius arises from the round point in which the os-hyoides terminates, and the cartilage of the os-hyoides, where its horns are joined to its body: it lies over the constrictor-superior, like a second layer: its uppermost point

touches the occipital bone, and its lower point is concealed by the constrictor-inferior. 9th, Constrictor-inferior, arises partly from the thyroid cartilage, and partly from the cricoid, and by its oblique progression it also overlaps the lower part of the constrictor-medius. This constrictor-inferior, like the two former muscles, meets its fellow in a tendinous middle line; and when the morsel is admitted into the pharynx, by the dilatation of its arches, it is pushed down into the œsophagus, by the united force of these three constrictor-muscles. 10th, The œsophagus is a continuation of the larynx, it lies flat upon the back-bone, and is covered through its whole length by a muscular coat, which is formed not of circular fibres, like the pharynx, but chiefly of fibres running according to its length. 11th, Vaginalis gulæ, is that muscle, which like a sheath surrounds the whole membranous tube of the œsophagus.

There are three muscles in the tongue: their thickness constitutes its chief bulk, and their action performs all its motions. 1st, The hyo-glossus arises from the whole length of the os-hyoides, and forms the side of the tongue: it rounds the back of the tongue, and pulls down its edges. 2d, Genio-hyo-glossus, arises by a narrow pointed origin behind the symphisis of the chin, and as it proceeds towards the tongue, and the base of the os-hyoides, spreads out like a fan, and (with its radii extending upward and backward) constitutes the greatest portion of the bulk of the tongue; for it plies in the centre, from the root to the tip, and its fibres having a radiated mechanism, cause the tongue to perform every possible motion. The fibres which proceed backward thrust the tongue out of the mouth, and the middle fibres make the tongue hollow in its centre, and elevate its tip and root. 3d, The lingualis is an irregular bundle of fibres, running according to the length of the tongue, and lying betwixt the hyo-glossus, and genio-hyo-glossus: as this muscle is in the centre of the tongue, and unconnected with any bone, it is therefore called the lingualis, or muscle of the tongue. From these simple facts, we perceive that each fleshy fibre has its particular use, and that the Eternal has not only created, but wisely adapted it to fulfil its intended purpose, in the mechanism and functions of the animal economy, with unerring precision and perfect accuracy.

There are three muscles that move the scapula, or shoulder-blade, upward and backward. 1st, The trapezius, is one of the most beautiful muscles of the body: the two conjoined, one on each shoulder, and on the neck, extend from the tip of the one shoulder to the tip of the other, and from the nape of the neck, down to the loins: when they reach the top of the neck, they become tendinous, and are named ligamentum nuchæ, or ligament of the neck. From this point down the neck, the trapezius does not lay hold of the spine, but does so when it reaches the two last vertebræ of the back. It is implanted into more than one-third of the collar-bone, next the shoulder, into the tip of the acromion, or shoulder top, and the whole length of the spine, from which the acromion rises. But its fibres arising from along the neck and back, and converging almost to a point, have very different effects, according to the different fibres that act. It moves and rolls the scapula, pulls the head backward, bends the neck, and is a powerful muscle of respiration. 2d, Levator scapulæ, is a small thin slip of flesh, arising from the four or five uppermost vertebræ of the neck, by three or four and sometimes five distinct heads. The heads join to form a thin flat stripe of muscle about three inches broad, which is fixed by a flat thin tendon to the upper corner of the shoulder-blade. This muscle pulls up the scapula when we shrug our shoulders. 3d, Rhomboideus arises first from the three lower spinous processes of the neck, and is implanted into the base of the scapula; and second, from the spinous processes of the first four vertebræ of the back, and runs into the base of the scapula. It has been sometimes reckoned two muscles, the major and minor; but most anatomists consider it only one muscle with two divisions. It raises the shoulder-blade, and carries it backward. The muscles that move the scapula forward, come from the breast; upward from the neck; backward from the spine; and downward from the ribs.

There are three muscles that move the shoulder-blade downward and forward. 1st, Serratus major anticus, arises from all the ribs, and by distinct portions from each rib, and lies on the side of the chest. The distinct portions betwixt the ribs are called digitations or fingers; but the chief part of the muscle lies under the shoulder-blade, where it is thick and fleshy, and forms part of the cushion on which the scapula glides. It terminates in the whole length of the line, called the base of the scapula: when the entire muscle acts, it pulls the shoulder-blade downward and forward: when only the lower portions act, they pull the lower angle of the scapula forward: when the upper part acts along with the pectoral muscle, the tip of the shoulder is fixed and pulled towards the chest, and the lower corner of the scapula is rolled backward. But its most important action is to fix the scapula, expand the ribs, and perform respiration, or breathing. 2d, The pectoralis minor lies under the pectoralis major, close upon the ribs. It sometimes arises from the third, fourth, and fifth ribs; sometimes from the second, third, and fourth; and sometimes only from the third and sixth. Its three digitations are very thick and fleshy, and converge into a smaller muscle, terminating in a point attached to the apex of the coronoid process. It pulls the coronoid process forward and downward, and rolls the shoulders. 3d, Subclavian muscle, arises by a flat tendon from the cartilage of the first rib, and becoming flat and fleshy, runs betwixt the first rib and the collar-bone. It is inserted along the whole clavicle, beginning about two inches from the sternum, and pulls the shoulder downward. The shoulder-blade is moved upward by the levator scapulæ, and trapezius; backward, by the rhomboideus, and the middle portions of the trapezius; downward and backward by the lowest order of fibres in the trapezius; downward and forward by the serratus major anticus; directly downward by the serratus, assisted by the subclavius; balanced by the trapezius; and directly forward by the pectoralis major.

The arm is joined to the body and moved by numerous powerful muscles, and is fixed to the breast by the ligaments of the collar-bone. The muscles that move the shoulder-blade lie upon the trunk; those that move the arm lie upon the shoulder-blade; those that move the fore-arm lie upon the arm; and those that move the hand and fingers lie upon the fore-arm. But as the arm requires easy circular motions, it has a multiplicity of joints to perform them. It has the wrist, for turning it round; the elbow, for its hinge-like motions; and the shoulder-joint, on which it rolls; and to assist all these, the moveable shoulder-blade becomes the centre of their motions; for after a certain point of elevation, the motion of raising the arm is performed by the action of the scapula upon the trunk; when our shoulder-bone is raised to a horizontal position, it is checked by the acromion or upper part of the shoulder-joint which hangs over it; and if we elevate our arm still higher, the scapula rolls, turning upon the point of the clavicle, or collar-bone, and as it turns, it glides easily upon those muscles, which lie like a fleshy cushion betwixt it and that part of the trunk over which it is so usefully placed, by the glorious Author and Architect of the universe.

GEOLOGY.

CHAPTER V.

CLASSIFICATION AND MINERALOGICAL DESCRIPTION OF THE STRATIFIED OR AQUEOUS ROCKS.

The term rock is usually applied to hard stony substances, occurring either in layers or in amorphous (1) masses. In geology, however, the term is applicable to all substances, without reference to their hardness or softness, which occur in large masses in the crust of the globe. Thus, granite, marl, coal, and clay, are equally entitled to the name. The propriety of thus fixing the definition of the term will appear palpable, if we take the fact into consideration, that there is every degree of hardness to be found in the various mineral compounds, from the most indurated quartz rock to the softest clay. When we speak, therefore, of rocks, it is to be understood it is of those substances which compose the stratified and unstratified masses found at, or near, the surface of the earth.

Rocks have been classed mineralogically into the siliceous, the argillaceous, and calcareous; as quartz or silica clay or lim prevail.

As to their nature and origin, they have been divided into the igneous and aqueous; the igneous being classed into the plutonic and volcanic, and the aqueous into the metamorphic or altered, and the fossiliferous.

Again, as to their comparative age, into the primary, the transition, the secondary, the tertiary, and post-tertiary or recent.

All these modes of classification will appear necessary when we take into consideration the causes for adopting them. The reasons for the first mode of classification must be abundantly evident from the observations made in the last chapter, with respect to the great predominancy of quartz or silica, clay, and lime, as the constituents of mineral bodies, and consequently of rocks.

Every one has heard of the nature of those masses of molten matter which issue from the craters of volcanoes, overflowing large tracts of the surrounding countries, and forming beds sometimes of very considerable thickness,—in short, that many districts are wholly, or almost wholly, composed of matter so formed. Such lavas generally arrange themselves round the volcano, and give it a conical form. The substances thus produced are denominated volcanic rocks. There are also rocks which yield every evidence of their having been once in a fused state, partaking of many of the characters of lava, and other volcanic rocks; but these occur in countries where there is no volcanic crater, and they frequently cover the regular stratified rocks to a great extent. These are considered to have issued from the inferior parts of the earth through openings, or fissures, and to have accumulated in immense masses at the bottom of the ocean, from which they have been subsequently upheaved. These are the whinstones, or trap rocks, of Scotland, England, Ireland, &c. They generally occur in irregular hilly ridges, and not in conical hills or mountains like those which have issued from the volcanic crater. This class of rocks is also denominated volcanic. We find also another class of rocks, but of similar composition, occurring in the form of walls or dykes in the stratified rocks, to which we ascribe a similar origin, and also denominate trap.

The plutonic rocks, consisting of granite, sienite, and some porphyries, are those which are of a crystalline structure like the volcanic rocks, though not so much so, but they are distinct from them inasmuch as though "they pierce through other strata, they never, or rarely, have been found to rest upon them as if they had overflowed." "As it is admitted," says Mr Lyell, "that nothing strictly analogous to these crystalline productions can now be seen in the progress of formation on the earth's surface, it will naturally be asked, on what data we can find a place for them in a system of classification founded on the origin of rocks. First, then, in regard to the plutonic class: a passage has been traced from various kinds of granite into different varieties of rocks, decidedly volcanic; so that if the latter are of igneous origin, it is scarcely possible to refuse to admit that the granites are so likewise. Secondly, large masses of granite are found to send forth dykes and veins into the contiguous strata, very much in the same way as lava and volcanic matter penetrate aqueous deposits; both the massive granite and the veins causing changes analogous to those which lava and volcanic masses are known to produce; but the plutonic rocks differ from the volcanic, not only by their more crystalline texture, but also by the absence of tuffs and breccias, which are the products of eruptions, at the earth's surface: they also differ by the absence of pores or cellular cavities, which the entangled gases give rise to in ordinary lava. From these and other peculiarities, it has been inferred that the granites have been formed at great depths in the earth, and have cooled and crystallized slowly under the influence of enormous pressure where the contained gases could not expand. The volcanic rocks, on the contrary, have also risen up from below, have cooled from a melted state more rapid, upon or near the surface. From these hypotheses of the great depth at which the granites originated, has been derived the term plutonic rock, which they have received to distinguish them from the volcanic."

The propriety of the terms *aqueous* and *igneous* must now appear sufficiently explicit to the reader, when applied, in the one case, to those rocks which, like lava, have been once in a state of fusion, and in the other, to those which have originated from sedimentary deposition at the bottom of water. The metamorphic rocks are those stratified deposits which have been altered from their original earthy condition into a crystalline or semi-crystalline texture by heat, such as gneiss, mica slate, clay slate, hornblende slate, &c. These rocks are also termed non-fossiliferous, because they have never been found to contain any trace of animal or vegetable remains; and also primary from the same cause,—it being concluded by some geologists that they were deposited prior to the creation of organic life upon the globe. They have also been termed the crystalline strata, from their being more of a crystallized structure than the newer formations.

The term primary has been objected to by Mr Lyell as improper; because he contends that even gneiss and mica slate may have been produced from the waste of previously existing strata, of which the monuments remain in the enormous accumulations of these rocks. And all remaining traces, obliterated by conversion into granite, he considers gneiss a passage from mica slate into granite, and mica slate now in the progress of becoming gneiss, and ultimately granite, may have originally differed very little from other sedimentary deposits. Mr Lyell has used much ingenuity, and no small labour, in endeavouring to build up this his favourite theory. He has certainly adduced facts to show that rocks of all ages, when subjected to igneous action, undergo a certain degree of metamorphism; but the evidence adduced from these has never, we confess, been able to show us that gneiss has not resulted from the debris of granites, and that mica slate has not been the product of decomposed gneiss, instead of *vice versa*, as his theory would lead us to suppose. In the mean time we consider the term primary a very good term for the non-fossiliferous strata, and use it as such only.

Transition is certainly a very objectionable term, as the strata of every period indicate what the term is meant to express—an alteration of condition. Yet no better has been yet suggested to designate the period between that of the introduction of marine animal life, to that of the creation of land animals, of which we have the first trace in the newest of the secondary deposits, namely, the new red sandstone: we therefore coincide with Dr Buckland in this use of the term. The term secondary comprehends all those rocks which are newer than the coal series, and older than the tertiary—the tertiary all those rocks which contain recent species of mollusca, and animals allied to the existing tribes, but which were deposited prior to the creation of the human species.

We shall now present the reader with a systematic arrangement of British strata.

TABLE OF BRITISH DEPOSITS.

Recent deposits and accumulations.

Vegetable Soils—peat, mud, clay, sand, and gravel, deposited during the historic era, by rivers, lakes, floods, &c.

STRATIFIED ROCKS.

Tertiary strata.

Crag, 167 yards.	Upper Crag—Marine shells, pebbles, sand, &c.
	Lower or Coralline Crag—Marine shells and corals in sand or coarse limestone.
Fresh Water Marls, 33 yards.	Upper Fresh Water Beds—Marly limestone and clay.
	Estuary Beds—Marine and estuary clays.
	Lower Fresh Water Beds—Marly limestone and clay.
London Clay, 200 to 600 yards.	London Clay—Clay with shells, &c.
	Plastic Clay—Variegated sands, clays, lignite.

Secondary strata—Cretaceous series.

Chalk Formation, 200 to 330 yards.	Upper Chalk—Soft white chalk with layers.
	Lower Chalk—Hard white chalk with few or no flints.
	Chalk Marl—Soft clayey chalk.
Green Sand, 160 yards.	Upper Green Sand—Green sand.
	Gault—Blue marl or clay.
	Lower Green Sand—Irony brown or green sands with limestone in some places.

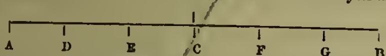
Oolitic series.

Wealden Formation, 300 yards.	Weald Clay—Clays with calcareous or limestone beds occasionally interposed.
	Hasting Sands—Sands, clays, and calcareous grits.
	Purbeck Beds—Clay or marls, and beds of limestones of various kinds.
Upper Oolite, 130 yards.	Portland Oolite—Limestone and sands.
	Kimmeridge Clay—Blue clay with septaria.
Middle Oolite, 150 yards.	Upper Calcareous Grit—Calcareous sandstone.
	Coral Rag—Oolitic coralline limestone.
	Lower Calcareous Grit—Calcareous sandstone.
	Oxford Clay—Blue clay with septaria.
	Killoway Rock—Calcareous sandstone.

a division to be performed. In conformity with this view of the subject, $\frac{17}{5}, \frac{34}{10}, \frac{51}{15}$ are fractions; and the term fraction may even extend to whole numbers: for example, $\frac{17}{1}, \frac{34}{2}, \frac{51}{3}$, are fractions and all equal to 17.

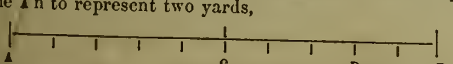
4. According to our new notation, which we thus find includes all our former ideas of number, and others besides, the part above the line is called the *numerator*, and that beneath, the *denominator*, and both of these are called *terms* of the fraction. The *numerator* takes its name from its expressing the *number* of parts of a certain kind that are taken; the *denominator*, from its giving *name*, as *sevenths, ninths*, to the parts into which the unit is divided. As long as the numerator is less than the denominator, the fraction is less than 1; thus, $\frac{19}{20}$ is less than 1: for the denominator is the unit divided into 20 parts, and we must therefore have 20 such parts to make 1; but the fraction $\frac{19}{20}$ shows that the quantity considered contains only 19 such parts. Similarly, $\frac{7}{11}, \frac{11}{12}, \frac{33}{35}$, are all less than 1, and are sometimes, for that reason, termed *proper fractions*. On the other hand, when the numerator is equal to, or exceeds the denominator, the fraction is equal to, or greater than 1; thus $\frac{5}{5}$ is equivalent to 1, for it is the fifth part of 1 repeated 5 times, or it is the magnitude of each of the parts which result from dividing 5 into 5 equal parts. Similarly, $\frac{4}{4}, \frac{9}{9}, \frac{12}{12}, \frac{29}{29}$, are all equal to 1 and consequently equal to each other. Again, $\frac{12}{7}$ is greater than 1: for the unit is here divided into 7 parts only, and the numerator consists of 12 or $7+5$ such parts, that is of a whole *unit* and *five-sevenths* of a unit over, or using signs $\frac{12}{7} = 1\frac{5}{7}$. Expressions such as $\frac{5}{5}$, $\frac{12}{7}$, in which the numerator is equal to or exceeds the denominator, are usually called *improper fractions;* and when an expression consists of a whole number and a fraction, as $1\frac{5}{7}$, it is commonly called a *fractional* or *mixed number.*

5. There are two ways in which a fraction may be considered. If we have, for instance, such a fraction as $\frac{2}{3}$, we may regard it either as the third part of 2, or as twice the third part of 1. This is, indeed, plain from the foregoing discussion upon the division of 17 by 5; but in order to bring the principle more prominently before the mind, let the line A B be two yards;



and divide each of the yards A C and C B into three equal parts. Then because A E = E F = F B, and divide the length A B into three parts, A E is the third part of 2: it is therefore $\frac{2}{3}$. But A E is twice A D, and A D is the third part of one yard A C; and a third of a 1 is $\frac{1}{3}$. Therefore $AE = \frac{2}{3}$ is twice $\frac{1}{3}$. Hence to get a length equal to two-thirds of a yard, it makes no difference whether we divide *two yards* into three equal parts and take *one* of them, or whether we divide *one yard* into three equal parts and take *two* of them. The symbol $\frac{2}{3}$ is made to stand for both these operations, since they both lead to the same result. By the same sort of reasoning we conclude that *one-fifth* of *three*, and *three-fifths* of *one*, are identical and truly expressed by $\frac{3}{5}$; and the double interpretation may be extended to all other cases.

6. The meaning may appear somewhat ambiguous when the numerator of the fraction is greater than the denominator. For example, according to the latter interpretation, $\frac{8}{5}$ would mean that 1 is divided into five equal parts, and that 8 of them are to be taken. The explanation is, however, very easy: the case requires simply that as many units be each divided into fifths as will give more than 8 such parts, and that 8 of them are to be taken to form the numerator of the fraction. Thus, supposing the line A B to represent two yards,



divided each into five equal parts; the whole number of parts is 10, and of these we are to take 8, namely, A D, to form our fraction: and as each part is a fifth of one yard, 8 such fifths is truly expressed by $\frac{8}{5}$.

7. It is commonly reckoned necessary in arithmetical works to give a rule for finding the integers contained in an improper fraction. The necessity of such a rule has, however, been obviated by the explanation that every fraction may be regarded as a division to be performed. But if wanted it is this: *Divide the numerator by the denominator.* For example, how many units are there in $\frac{23}{6}$? Since $\frac{6}{6} = 1$, it is plain that as often as $\frac{23}{6}$ contains $\frac{6}{6}$ so many units there will be. Now $23 = 6 + 6 + 6 + 5$; therefore,

$$\frac{23}{6} = \frac{6}{6} + \frac{6}{6} + \frac{6}{6} + \frac{5}{6} = 1 + 1 + 1 + \frac{5}{6} = 3 + \frac{5}{6} \text{ or } 3\frac{5}{6}$$

and this agrees with the rule; for $23 \div 6$ give 3 for quotient and 5 for remainder; and the sixth part of 5 is $\frac{5}{6}$; therefore

$$23 \div 6 = 3 + \frac{5}{6} \text{ or } 3\frac{5}{6}$$

Similarly

$\frac{39}{5} = 39 \div 5 = 7 + \frac{4}{5}$	$\frac{150}{14} = 150 \div 14 = 10\frac{10}{14}$
$\frac{83}{11} = 83 \div 11 = 7 + \frac{6}{11}$	$\frac{307}{15} = 307 \div 15 = 20\frac{7}{15}$

8. The converse of this problem is the conversion of whole and mixed numbers into fractions, and is frequently needed. The rule is this: *Multiply the integral part by the given denominator and the product increased by the numerator of the fractional part (if there be any such part) is the numerator of the new fraction.*

As an example, express 3 in *fifths*. Since every 1 in 3 is $\frac{5}{5}$, therefore $3 = \frac{5+5+5}{5} = \frac{5 \times 3}{5} = \frac{15}{5}$.

Again, how many eighths in $7\frac{3}{8}$? In 7 there are, reasoning as before, 7×8, or 56-*eighths;* therefore 7 and 3-*eighths* must contain $56 + 3$, or 59-*eighths;* consequently $7\frac{3}{8} = \frac{59}{8}$.

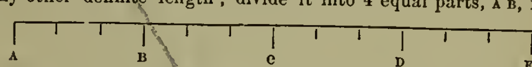
Similarly

7 expressed in ninths is $\frac{63}{9}$	$9\frac{11}{12}$ expressed in twelfths is $\frac{119}{12}$
$7\frac{1}{3}$ expressed in thirds is $\frac{22}{3}$	3 expressed in hundredths is $\frac{300}{100}$

These two processes are the inverse of each other, and mutually prove each others' results.

9. We come now to by far the most valuable property of a fraction. It is one, however, which we anticipated when we showed (Art. 14, page 142,) that the dividend and divisor may be either multiplied or divided by the same without affecting the quotient. As the greater part of the operations upon fractions have an immediate reference to the principle involved, we cannot be too particular in impressing it upon the mind of the student. It is the following:—

The value of a fraction is not altered by multiplying both its numerator and denominator by the same quantity. That is, $\frac{3}{4}$ is the same as $\frac{9}{12}$ or we shall obtain the result by dividing 1 yard into 12 parts, and taking 9 of them, and by dividing it into 4 parts and taking 3 of them. To prove this, let A E be a yard or any other definite length; divide it into 4 equal parts, A B, B C,



C D, and D E, and divide each of these parts into 3 equal parts; then A D is $\frac{3}{4}$. But it is also $\frac{9}{12}$, for the whole line is divided into 12 equal parts, and A D contains 9 of them; that is, we get the same length by dividing a yard into 12 equal parts, and taking 9 of them, as we get by dividing it into 4 equal parts, and taking 3 of them. We have, therefore, no difficulty in concluding generally that $\frac{3}{4}$ and $\frac{9}{12}$, are the same thing. It follows from this that every fraction admits of innumerable alterations in its form, without suffering any change of value.

Thus

$$\frac{1}{2} = \frac{2}{4} = \frac{3}{6} = \frac{4}{8} = \frac{5}{10} = \frac{6}{12} = \frac{7}{14} = \frac{8}{16} = \text{\&c.}$$

$$\frac{2}{7} = \frac{4}{14} = \frac{6}{21} = \frac{8}{28} = \frac{10}{35} = \frac{12}{42} = \frac{14}{49} = \frac{16}{56} = \text{\&c.}$$

On the same principle, it is shown that the terms of a fraction may both be divided by any number without any alteration of its value. This hardly needs demonstration: for $\frac{3}{4}$ and $\frac{9}{12}$ are the same, and $\frac{3}{4}$ is made from $\frac{9}{12}$, by dividing both the numerator and denominator by 3.

10. Though the two fractions $\frac{3}{4}$ and $\frac{9}{12}$ are the same in value, and either of them may be used for the other without error, yet

the first is more convenient than the second, not only because we have a clearer idea of *three-fourths* of a yard than of *nine-twelfths* of it; but the numbers in the first being smaller, they are more conveniently added, subtracted, multiplied, or divided. It is therefore useful, when a fraction is given, to find out whether its terms have any common divisor or measure. The method of doing this was explained in our last chapter; where it was likewise shown that when two numbers are divided by their greatest common measure, the quotients are *prime* to each other. When the terms of a fraction are reduced to this condition; that is, incapable of being both measured by any number greater than 1, the fraction is then said to be reduced to its *lowest terms*, and cannot be expressed more simply or by any fraction having a smaller numerator and denominator. From all this it appears that a fraction is reduced to its lowest terms when its numerator and denominator are divided by their greatest common measure, or have all their common factors expunged.

It frequently happens that the greatest common measure is evident on inspection, as in the following instances where the common factors are accented :—

$$\frac{8}{12}=\frac{2\times 4'}{3\times 4'}=\frac{2}{3} \qquad \frac{9}{81}=\frac{1\times 9'}{9\times 9}=\frac{1}{9} \qquad \frac{28}{35}=\frac{4\times 7'}{5\times 7'}=\frac{4}{5}$$

$$\frac{12}{48}=\frac{1\times 12'}{4\times 12'}=\frac{1}{4} \qquad \frac{14}{21}=\frac{2\times 7'}{3\times 7'}=\frac{2}{3} \qquad \frac{24}{21}=\frac{8\times 3'}{7\times 3'}=\frac{8}{7}$$

When the terms of the fraction are large numbers, it then becomes necessary to apply the rule for finding the greatest common measure of two numbers in order to eliminate the common factor of the terms. The following are instances :—

$$\frac{2433}{13787}=\frac{3\times 811}{17\times 811'}=\frac{3}{17} \qquad \frac{8888}{403596}=\frac{22\times 404'}{999\times 404'}=\frac{22}{99}$$

$$\frac{1397}{2921}=\frac{11\times 127'}{23\times 127'}=\frac{11}{23} \qquad \frac{13786}{93208}=\frac{113\times 122'}{764\times 122'}=\frac{113}{764}$$

Where the terms of the fraction are already in factors, any one factor in the numerator may be divided or struck out, provided the same is done with some one factor in the denominator. —*Principle*, the same as before.

$$\frac{4\times 7\times 5}{8\times 6\times 10}=\frac{1'\times 7\times 1}{2'\times 6\times 2'}=\frac{7}{2\times 6\times 2}=\frac{7}{24} \qquad \frac{21\times 16\times 4}{14\times 32\times 8}=\frac{3}{8}$$

$$\frac{12\times 18\times 33}{18\times 24\times 11}=\frac{2'\times 3'\times 3'}{3'\times 4'\times 1'}=\frac{1'\times 1'\times 3}{1'\times 2'\times 1'}=\frac{3}{2} \qquad \frac{7\times 25\times 30}{28\times 35\times 100}=\frac{3}{56}$$

11. Since the relative magnitudes of fractions depend upon two numbers, it is not always easy, at first view, to pronounce which of two quantities so expressed is the greater, especially if the terms are high numbers. For instance, take $\frac{4}{5}$ and $\frac{13}{15}$. Before we can compare their values, or express their sum or difference by a single number, we must effect such a change on one or both of them, that their component units shall be the same. Let the terms of $\frac{4}{5}$ be multiplied by 15, and the terms of $\frac{13}{15}$ by 5, then $\frac{4}{5}$ becomes $\frac{60}{75}$, and $\frac{13}{15}$ becomes $\frac{65}{75}$, and as these new fractions have the same values as those given (art. 9.) and express parts of the same unit, *for the denominator in both is the same*, we are able to pronounce on their relative magnitudes, and as we shall afterwards see, are able to find their sum or difference with comparative facility.

To show how this is done, we shall take an example. Let the proposed fractions be $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{6}$, $\frac{2}{3}$. Multiply both terms of $\frac{1}{2}$ by $4\times 6\times 3$; both terms of $\frac{3}{4}$ by $2\times 6\times 3$; both terms of $\frac{5}{6}$ by $2\times 4\times 3$; both terms of $\frac{2}{3}$ by $2\times 4\times 6$; then it appears that

$$\frac{1}{2}\text{ is }\frac{1\times 4\times 6\times 3}{2\times 4\times 6\times 3}\text{ or }\frac{72}{144} \qquad \frac{5}{6}\text{ is }\frac{5\times 2\times 4\times 3}{6\times 2\times 4\times 3}\text{ or }\frac{120}{144}$$

$$\frac{3}{4}\text{ is }\frac{3\times 2\times 6\times 3}{4\times 2\times 6\times 3}\text{ or }\frac{108}{144} \qquad \frac{2}{3}\text{ is }\frac{2\times 2\times 4\times 6}{3\times 2\times 4\times 6}\text{ or }\frac{96}{144}$$

We have thus succeeded in making all the given fractions take the same denominator, 144, and the method by which it is done is as follows :—

Multiply each numerator by all the given denominators except its own, for the numerator of the equivalent fraction, and take the product of ALL *the denominators for its denominator.*

This is the rule commonly given; and it is at once obvious, that it must always succeed in forming a new set of fractions, having a common denominator. But on examining the resulting fractions of the foregoing example, we find that all the numerators and the common denominator are divisible by 12; and we have already shown that this division does not affect their value. Making therefore this division, we get

$$\frac{6}{12}\text{ instead of }\frac{72}{144} \qquad \frac{10}{12}\text{ instead of }\frac{120}{124}$$

$$\frac{9}{12}\ \ldots\ \frac{108}{144} \qquad \frac{8}{12}\ \ldots\ \frac{96}{144}$$

These are likewise fractions equivalent to those giving and having a common denominator; but the common denominator is a much smaller number, and therefore they are a simpler answer to the question than the first fractions found. Our first object is to find equivalent fractions having a common denominator; but as a matter of course, it is of great importance that the denominator be as small as possible, and this is always the case when the numerators and this denominator have no common measure. Again, the common denominator which fulfils these conditions, is the least common multiple of all the denominators given, and is found as explained in our last Chapter, (Art. 10.) The method of proceeding will be best understood by an example. Let the given fractions be

$$\frac{1}{2}\quad \frac{2}{3}\quad \frac{3}{4}\quad \frac{7}{6}\quad \frac{9}{10}\quad \frac{5}{12}\quad \frac{17}{18}\quad \frac{8}{21}$$

Find the least common multiple of these denominators: it is 1260, and the equivalent fractions to be found, cannot obviously have a less common denominator than this, and it needs not be greater. Taking it therefore as the denominator wanted, we find a set of multipliers for the numerators of the given fractions, simply by dividing the multiplier by all the denominators in succession.

Thus $1260 \div 2 = 630$ $\quad 1260 \div 4 = 315$ $\quad 1260 \div 10 = 126$
$1260 \div 3 = 420$ $\quad 1260 \div 6 = 210$ $\quad 1260 \div 12 = 105$
$1260 \div 18 = 70$ $\quad 1260 \div 21 = 60$

We now multiply every given numerator by the result of its denominator in the preceding list, for the numerator of the equivalent fraction, and write 1260 for the common denominator of all, as follows :—

$1\times 630 = 630$; therefore $\frac{1}{2}$ is $\frac{630}{1260}$ | $9\times 126 = 1134$; therefore $\frac{9}{10}$ is $\frac{1134}{1260}$

$2\times 420 = 840$; therefore $\frac{2}{3}$ is $\frac{810}{1260}$ | $5\times 105 = 525$; therefore $\frac{5}{12}$ is $\frac{525}{1260}$

$3\times 315 = 945$; therefore $\frac{3}{4}$ is $\frac{945}{1260}$ | $17\times 70 = 1190$; therefore $\frac{17}{18}$ is $\frac{1190}{1260}$

$7\times 210 = 1470$; therefore $\frac{7}{6}$ is $\frac{1470}{1260}$ | $8\times 60 = 480$; therefore $\frac{8}{21}$ is $\frac{480}{1260}$

The followiug instances may be managed exactly in the same way, and will afford sufficient exercise in the rule, should they be worked over with care.

Fractions given.						Reduced to a common Denominator.					
$\frac{1}{2}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{1}{6}$	$\frac{3}{8}$	$\frac{5}{12}$	$\frac{12}{24}$	$\frac{16}{24}$	$\frac{18}{24}$	$\frac{4}{24}$	$\frac{9}{24}$	$\frac{10}{24}$
$\frac{1}{3}$	$\frac{2}{7}$	$\frac{3}{14}$	$\frac{12}{21}$	$\frac{3}{4}$		$\frac{28}{84}$	$\frac{24}{84}$	$\frac{18}{84}$	$\frac{48}{84}$	$\frac{63}{84}$	
$\frac{3}{4}$	$\frac{5}{9}$	$\frac{9}{10}$	$\frac{7}{12}$	$\frac{1}{18}$		$\frac{135}{180}$	$\frac{100}{180}$	$\frac{162}{180}$	$\frac{105}{130}$	$\frac{10}{180}$	
$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$		$\frac{30}{60}$	$\frac{20}{60}$	$\frac{15}{60}$	$\frac{12}{60}$	$\frac{10}{60}$	
$\frac{5}{8}$	$\frac{7}{12}$	$\frac{11}{18}$	$\frac{9}{20}$			$\frac{225}{360}$	$\frac{210}{360}$	$\frac{220}{360}$	$\frac{162}{360}$		
$\frac{1}{9}$	$\frac{3}{5}$	$\frac{7}{15}$	$\frac{5}{6}$	$\frac{16}{24}$	$\frac{11}{27}$	$\frac{120}{1080}$	$\frac{648}{1080}$	$\frac{504}{1080}$	$\frac{900}{1080}$	$\frac{855}{1080}$	$\frac{440}{1080}$

ANATOMY AND PHYSIOLOGY.

CHAPTER VII.

THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

I WILL now take a short review of the uses of the principal portion of the thirty-one muscles which I have last described. 1st, The palmaris longus, the flexor carpi radialis, and flexor carpi ulnaris, are the three principal flexors or benders of the wrist. 2d, The extensor carpi ulnaris, the extensor radialis longior, and extensor radialis brevior, are the three principal exteusors or stretchers

of the wrist. 3d, The chief pronators of the hand are, 1st, the pronator teres; 2d, the pronator quadratus; and 3d, the flexor muscles. 4th, The three supinators of the hand are, 1st, the supinator longus; 2d, supinator brevis; and 3d, the biceps. 5th, The three extensors of the fingers are, 1st, extensor communis digitorum; 2d, extensor primi digiti; and 3d, extensor minimi digiti. 6th, The three extensors of the thumb are, 1st, the extensor primus pollicis; 2d, extensor secundus pollicis; and 3d, extensor tertius pollicis. 7th, The three flexors of the thumb, are, 1st, flexor digitorum sublimis; 2d, flexor digitorum profundus; and 3d, the flexor longus pollicis. All the muscles that arise from the inner knob or condyle of the humerus or arm-bone, are flexors; but from the external condyle, they are extensors; those inserted into the radius turn the wrist, by rolling the radius on the ulna. Their mechanism and action are beautiful, simple, and perfect. We will now pass on to the muscles of the ribs, and respiration.

The whole of the back is covered with strong muscles related to the arm, ribs, and spine; but the muscles appropriated to the ribs, which perform no other function than respiration, are, 1st, The serratus posticus superior, which comes from the neck, extends over the ribs and pulls them downward. 2d, The serratus inferior posticus, which comes from the vertebræ of the loins, lies flat on the lower portion of the back, and pulls the ribs downwards. 3d, The twelve levatores costarum, which arise from the transverse processes of each vertebræ of the back; and each muscle going down to the rib below, raises it up when in action. 4th, The intercostal muscles, external and internal, fill up the spaces, crossing each other betwixt the ribs, and raise and depress the chest in respiration; to these may be added, the triangularis sterni, a muscle that lies within the chest, and pulls the ribs downward. The muscles of the ribs are appropriated to respiration, and unite their functions with the diaphragm and muscles of the abdomen; but in coughing, sneezing, speaking, smelling, &c., there are other muscles also brought into action besides these, belonging to the locally affected or irritated parts; and, whether individually or combined, display the infinite goodness, power, and wisdom, of our great Creator, in planning and accomplishing the mechanism and utility of the human body.

There are seven posterior muscles of the head and neck yet undescribed; 1. Splenius; 2. Complexus; 3. Trachelo-mastoideus; 4. Rectus minor; 5. Rectus major; 6. Obliquus-superior; 7. Obliquus inferior. The splenius, acting singly, turns the head obliquely to one side; but when both act, they pull the head downward. The complexus and trachelo-mastoideus, rectus major and minor, perform nearly the same action as the splenius. The obliquus superior and inferior, perform the short quick turnings of the head; all these muscles, more or less assist each other.

We will now proceed to the posterior muscles of the trunk, which form the greater portion of the fleshy substance of the back. 1. Quadratus lumborum, keeps the trunk erect, inclines it to one side, turns it on its axis, pulls down the ribs, and assists respiration; 2. Longissimus dorsi keeps the trunk erect, and bends the spine backward; 3. Sacro-lumbalis, takes a firm hold of the ribs, and not only pulls them down, but also assists in raising the trunk; 4. Cervicalis descendens, turns the neck to one side and bends it; 5. Transversalis colli lies between the trachelo-mastoideus and cervicalis descendens.

The surface of the back, betwixt the bulge of the ribs on each side of the chest, consists of innumerable hollows, processes, and points of bone, and is tied from point to point, and its hollows filled, with unequal bundles of tendon and flesh. The 1st bundle is divided into two sets, called spinalis cervicalis, and spinalis dorsi. It lies along the whole length of the neck and back, and raises the spine. The 2d bundle is called semi-spinalis dorsi; the 3d, multifidus spinæ, keeps the spine from bending too much forward; the 4th and 5th, inter-transversalis, and inter-spinalis, are useful in assisting us to perform the lateral and twisting motions of the loins. There are other two bundles called inter-transversalis-cervicis, and priores-lateralis, which complete the total number; all these muscles render the back firm, smooth, elastic, thick, and powerful, but especially the spine, which they clothe with flesh.

There are still other five muscles, lying on the fore part of the head and neck, which I may briefly mention, as they complete the catalogue of the muscles belonging to the spine: 1st, Rectus internus capitis major; 2d, Rectus internus minor; 3d, Rectus capitis lateralis; 4th, Longus colli; 5th, Scalenus. The first four muscles pull the neck to one side when acting single; but when acting double, they bend down the neck and head. The scalenus, in asthmatic patients, throws the head backward, that the chest may be more powerfully raised in coughing.

The muscles of the abdomen or belly are five on each side. 1st, The obliquus externus on each side, covers all the abdomen with its fleshy belly, and also the forepart of the abdomen with its white expanded tendon. Its fibres run obliquely from above, downward, and inward. 2d, The obliquus externus arises chiefly below in the haunch-bone, and all its fibres run from below upward. 3d, The transversalis lies under all the other muscles next the abdominal cavity. Its fibres run across and round the abdomen. 4th, The rectus runs on the fore part of the belly, in a straight line from the os pubis, or share-bone, to the sternum, or breast-bone. 5th, The pyramidalis is named after its shape, being pyramidal in form. It is a small neat conical muscle, arising from the os pubis, and having its apex turned upward. In some subjects this muscle is wanting.

These five abdominal muscles make the external covering for the belly, and by taking a firm hold of the pelvis (or basin) and trunk, they support and contain the bowels. They also bend and turn the trunk, and fix it firmly for the stronger action of the limbs. They keep the body steady in raising weights, bearing loads, and, alternately with the diaphragm or midriff, (an internal muscle which separates the abdomen from the chest,) they perform respiration. When the diaphragm presses down the bowels and enlarges the thorax or chest, we perform inspiration by drawing in our breath; when the abdominal muscles react and push back the diaphragm, the chest is compressed, and expiration, or letting out a breath, is accomplished. The abdominal muscles assist in emptying the bowels, expelling the child from the womb, and promote the circulation of the blood. But sometimes under these accumulated labours they give way, and burst frequently near the groin; and the bowels, protruding through the interstices of the muscular fibres, and enlarged natural passages, form hernia, or rupture, which is a very frequent attendant on old-age—especially in men who have often endured violent exercise, such as straining, pulling, raising heavy weights, and carrying oppressive loads.*

The two oblique muscles on one side, when in action, turn the body on its axis. But when they act on both sides, they co-operate with the rectus muscle in flattening the belly, and bending the body. The transverse muscles tighten the linea alba, a tendon which I am now about to describe. The recti muscles pull the ribs downward in breathing, flatten the body, and bend it forward.

I will now briefly notice a few other parts of the abdomen before I conclude the present essay. 1st, The linea alba is the common meeting of all the white thin flat tendons of the abdominal muscles in the centre of the belly, and forms the point toward which they all act. 2d, The linea semilunaris, is a white circular line, produced by the meeting of all the tendons of the abdomen on the edge of the rectus, to form its sheath, and is called the sheath of the rectus muscle. 3d, The umbilicus, or navel, is an opening in the centre of the belly, or the middle of the linea alba, through which the nourishing vessels have passed between the fœtus in utero, and the mother. These vessels in the adult degenerate into a ligament, which sometimes bursts, and forms umbilical hernia by the protrusion of the bowels. 4th, The inguinal ring of the abdominal muscles is an opening near the lower part of the belly above the pubis and groin, through which the spermatic cord passes in men, and the round ligament of the womb in women. It is formed by an oblique split in the tendon, commencing about an inch and a half above the pubis; and the spermatic cord in males (which passes through it), is formed by the vessels belonging to the testicle. 5th, The cremaster muscle is a thin slip of fibres coming from the internal oblique muscle, for suspending the testicle and drawing it up. It generally grows more fleshy with advancing old age. It is very large in dogs, and other animals in whom the weight of the testes require powerful support. Umbilical hernia, or rupture at the navel, is more frequent in females than

* I lately saw a case of abscess in an old man's groin, which a parochial surgeon mistook for rupture, and caused a truss to be placed over it. When the abscess was opened, nearly a pint of matter was discharged.

males; because the umbilical opening is slowly dilated in pregnancy and admits the bowels to protrude. Inguinal hernia, or rupture at the abdominal ring, is more frequent in men than women, because the round ligament of the womb being smaller than the spermatic cord, the inguinal ring is therefore closer and firmer in women than men. There seems to be a hereditary predisposition to hernia in certain families; and in these cases it is almost impossible to prevent the protrusion of the bowels from the most trivial causes in childhood.

The diaphragm, or interseptum, is an internal transverse vaulted partition betwixt the abdomen and chest; it is not only vaulted in the middle, but rises as high anteriorly as the breastbone, where it commences; while its lower and back parts begin almost as low as the pelvis, and from the false ribs and the vertebræ of the loins; and although it is convex towards the chest, and concave towards the belly, yet it becomes almost plain when it presses against the abdominal muscles in inspiration, but resumes its convexity, when by their reaction it is pushed back again into the chest in expiration. This alternate action and reaction constitute respiration or breathing; strictly speaking, however, there are two diaphragms—a greater before, and a smaller behind; in the centre betwixt them is a strong triangular tendon, and in the fleshy and tendinous fibres are several natural openings for the transmission of blood-vessels, ducts, and nerves, betwixt the abdomen and the chest.

Besides the important function of respiration, the diaphragm is not only useful in assisting to discharge fæcal matter and urine, from the bowels and bladder, but to expel the fœtus from the womb in parturition. Vomiting, hiccuping, yawning, crying, laughing, coughing, sighing, weeping, and indeed every audible emotion of joy and fear are diaphragmatic actions; and the celebrated Haller very justly remarks, "that the diaphragm is the noblest muscle after the heart."

The power of the muscles, the rapidity and durability of their action, are in some animals very extraordinary. The smallest common flea leaps with ease many hundred times the length and height of its body, by the agile power of the muscles of its legs. The wings of the humming bee move with such astonishing rapidity, that each muscular motion is imperceptible to the most discriminating eye. The lady-bird will fly 480 million times the length of its body in twenty-four hours. The eagle will fly fifty-four miles in an hour, and the canary-falcon 1125 miles in twenty-four hours. The antelope will run a mile in a minute; the elk a mile and a half in seven minutes; and some men have travelled a hundred miles in twenty-four hours. The human heart and arteries, beating at the rate of 64 per minute—pulsate 92,160 times every twenty-four hours; and often continue to beat without intermission and fatigue, for eighty or ninety years. The middle-coat of the arteries, and the entire heart, are muscular; and pulsation is accomplished by their elastic power, stimulated by the circulating blood.

The power and rapidity of muscular action do not always depend on the comparative magnitude and strength of the muscles. The sloth is many thousand times larger than the flea, yet the sloth will only travel fifty paces per day—a journey which the flea will perform with a few wonderful leaps. The worm is many hundred times larger than the ant, yet the former will only crawl a few inches per minute, while the latter is almost constantly in rapid exercise, and carries heavy loads to his nest. Although some sluggish animals have naturally very little muscular rapidity when performing locomotion, yet if wounded or irritated, their muscles are thrown into violent action, and convulsively move with rapidity and power. The worm that crawls only six inches a minute, when naturally left to the sluggish movements of its muscles, will writhe and fling its body to and fro when wounded, and dash itself on the ground with rapidity and violence. When muscles are spasmodically contracted, they are rigid and painful; and when cramp seizes our limbs, we feel the affected muscles stiff, hard, and inflexible as rods of iron. The pain is excruciating, and nothing can alleviate its severity, but the cessation of spasm. This intense suffering is produced by the muscular fibres pressing spasmodically on the nerves that ramify in the affected muscles, and supply their fibres with sensibility and nervous power. The middle coat of the stomach and bowels is muscular, and every person knows how speedily death is sometimes produced by its painful spasms. We ought never, by overstrained exertion, to injure our muscles. Insupportable fatigue sometimes ruptures their fibres, destroys their action and induces lameness. The muscles are perfectly fitted to perform every useful motion for which the Creator has designed them. If we employ them wrongfully, we injure their utility, thwart our Creator, and incur the penalty of wilfully violating the laws of nature.

We shall proceed to describe the muscles of the inferior parts of the body, and the lower extremities, in our next chapter, and finish the muscular system.

GEOLOGY.

CHAPTER VII.

VOLCANOES.

Whether the remarkable increase of temperature, experienced in descending beneath the surface of the earth, is the effect of radiation from a molten mass of incandescent matter, or whether it is occasioned by electric currents in the crust of the earth itself, is matter of dispute. Mr. Lyell favours the last hypothesis. "Some portions of earthy compounds," he says, "are daily resolved into their elements, and these on being set free are always passing into new combinations. These processes are almost always accompanied by evolution of heat, which is intense in proportion to the rapidity of the combinations. At the same time there is a development of electricity. It is well known that a mixture of certain materials sunk in the ground and exposed to moisture, gives out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that are near. Let a large quantity of clean iron filings be mixed with a still larger proportion of sulphur, and as much water as is necessary to make them into a firm paste; let the mixture be then buried in the earth, and the soil pressed down firmly upon it. In a few hours it will warm and swell so as to raise the ground, sulphureous vapours will make their way through the crevices, and sometimes flames will appear. There is rarely an explosion; but when this happens, the fire is vivid; and if the quantity of materials is considerable, the heat and fire will continue for a long time."

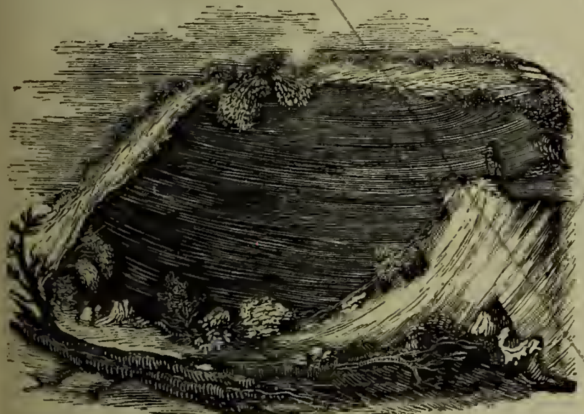
Instead, therefore, of referring volcanic action to the existence of an original central heat, it has been inferred that it may result from changes similar to that referred to, going on constantly in the crust of the earth. It has also been considered as probable, that the contact of water with the bases of the earths and alkalies in the subterranean regions may produce intense heat, and this theory is also supported by the fact, that volcanoes are in general situated near the coast. The hypothesis is familiarly illustrated by bringing a piece of potassium or sodium into contact with any moist substance: a rapid decomposition of the water ensues with the evolution of intense heat—the oxygen combining with the metal to produce potash or soda, according as the base of the one or the other is employed. A similar effect accompanies the action of water on the other metallic bases. But whether this affords a sufficient explanation of volcanic action, is a question upon which we are not yet prepared to give a decision. The fact is, however, before us; and whatever may be the cause or causes which produce volcanic phenomena, the burning mountain and the earthquake have at all times been objects of intense interest. We propose, therefore, to give the history of a few volcanic eruptions in various parts of the world, as narrated by Lyell and other naturalists.

A volcano generally consists of a cone-shaped hill, with a wide crater or chasm at its summit, from which issue flame and smoke, and in the times of great activity, rivers of burning lava, and showers of stone and ashes. The quantity of matter poured out is various. Sometimes it overspreads considerable tracts of the adjacent territory, and, when consolidated, forms a stratum of rock to the depth of many feet. Sometimes the showers of dust and stones are immense,—so much so, in fact, as in the cases of Pompeii and Herculaneum, to bury whole cities. The eruption of a volcano generally commences with a tremendous explosion, which is succeeded by others less loud, and the escape of gas and vapour from the mouth of the crater. Large fragments of solid

and disputes arose as to whom the property, which had thus shifted, should belong.

"From this account of Dolomieu," says Mr. Lyell, "we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact, than at a greater distance from the mountains —phenomena very common in other parts of Italy, at the junction of the Appenine and Subappenine formations."

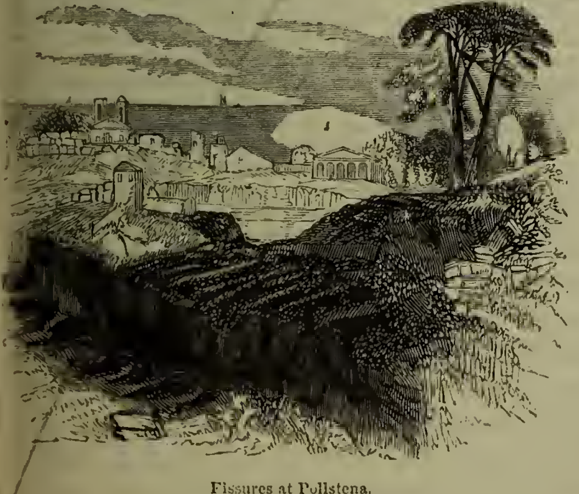
Many fissures and chasms which had been formed by the previous, were greatly widened by succeeding shocks. Grimaldi mentions a new ravine, in the territory of San Fili, half a mile long, 2½ feet broad, and 25 feet deep; another nearly a mile long, 105 feet wide, and 30 feet deep; another three-quarters of a mile long, 150 feet broad, and above 100 feet deep; and one at La Fortuna, nearly a quarter of a mile long, above 30 feet in breadth, and 225 feet deep; one, of which the following is a drawing, occurred near the town of Oppida, in the side of a hill, 500 feet long, and 200 feet deep.



Chasm formed near Oppida in 1783.

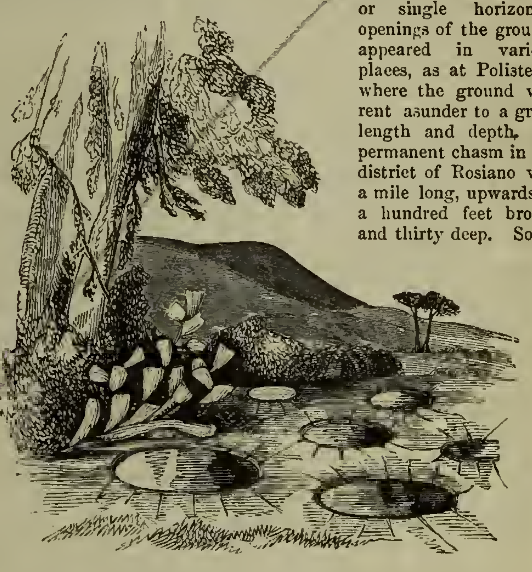
In the district of Fosolana, three gulfs opened; one, 300 feet square, and above 30 feet deep; another, about half a mile long, 15 feet broad, and above 30 feet deep.

Dolomieu and Sir William Hamilton made a personal examination of the surface of the Calabrias after the earthquakes, which continued from the beginning of 1783 to the close of 1786, and their survey illustrates the superficial changes produced by the action of such



Fissures at Polistena.

events. Those provinces have been subject to such visitations since the first Greek colonists landed on their shores, but the most terrible instances in modern times occurred in 1633 and 1783, in the latter of which Sicily largely participated. The soil of the mainland is chiefly composed of modern marine strata, immensely thick, generally of calcareous clay, of a very yielding nature, which was greatly disturbed, and assumed a variety of new forms, under control of the irresistible force acting upon it. The earth exhibited a variety of motions, whirling like a vortex, horizontal, or by pulsations or beatings from the bottom upwards. Valleys underwent extensive and striking alterations, through the precipitation into them of masses from the neighbouring hills. Fissures, radiating from a central point, or single horizontal openings of the ground, appeared in various places, as at Polistena, where the ground was rent asunder to a great length and depth. A permanent chasm in the district of Rosiano was a mile long, upwards of a hundred feet broad, and thirty deep. Some



Circular hollows at Polistena.

of those fissures, after swallowing up houses and men, closed and opened again, so that property was recovered, and the victims of the catastrophe were restored to the rites of burial. In the plains, a considerable number of circular hollows were formed, filled with water or sand, a consequence of the vorticose or whirling motion of the earth, and on digging down, they were found to be funnel-shaped, and the moist loose sand in the centre, up which the water spouted.

Section of one of the circular hollows formed in the plain of Rosiano.

About 40,000 persons are said to have perished amidst the catastrophes of the Calabrian earthquakes, and about 20,000 more died of the epidemics which ensued.

We shall conclude these accounts with a brief notice of three most remarkable and disastrous earthquakes; namely, those which occurred in Jamaica in 1692, at Lisbon in 1755, and at Melfi, near Naples, a few months ago.

The weather had been sultry in Jamaica up to the month of May, when it became very windy and rainy from the end of the month till the 7th of June,—it was excessively hot on the forenoon of that day, when not a cloud was to be seen in the sky, or a breath of air to fan the feverish cheek. A small trembling noise heralded a hollow loud rumbling like that of distant thunder; that was succeeded by a violent shock, which, in one minute, shook Port Royal to its foundation, and three parts of the town with its inhabitants sunk, and were instantly overwhelmed with the rush of the ocean. The houses and wharfs sunk to the

depth of from 8 to 6 fathoms below water—every where the ground heaved and swelled like an agitated sea, cracking, opening, and suddenly shutting; and in many instances, swallowing people alive. Some were totally buried, while others were squeezed to death, their heads only appearing above ground; larger openings swallowed whole houses, and some of these disgorged vast currents of water, which rose to considerable heights in the air, and were accompanied with the most obnoxious vapour and stench. The air, which had been a moment before so serene, became dull and red like an oven; while the most frightful noises came from the mountains, which were rending in pieces; while the ghastly and terror-stricken inhabitants ran from place to place, or were seen staggering and falling in all directions; many plantations with their houses were completely swallowed up; not far from Yellows, part of a mountain, after several removes, overwhelmed a whole family, and the greater part of a plantation more than a mile from its former site. A large hill near Port Morant was swallowed up, and a lake substituted in its place, 4 or 5 leagues in extent. The tops of the mountains in their fall huddled trees and earth before them in the most confused manner, and stopped the passage of several rivers for 24 hours, after which they found out new channels, and brought down to the sea many thousand tons of timber. In the harbour of Port Royal, the shock forced the vessels from their moorings; and the mast heads of several ships, together with the tops of the houses, were afterwards just seen projecting above the water at Yollhouse; the sea retired about a mile, and vast quantities of fish were left on dry land. About 2000 people are supposed to have perished in this catastrophe, and 3000 whites afterwards died of pestilential diseases, caused by the putrid effluvia which issued from the fissures in the earth which had been opened by the earthquake.

On the 1st of November 1755, the city of Lisbon was thrown into dismay by the sound of thunder rolling under the earth, which was immediately succeeded by a violent shock which destroyed the greater part of the city, with 60,000 people who perished in the course of ten minutes. Some of the largest mountains in Portugal were shaken to their very foundations, and cleft and rent in a most extraordinary manner,—some of them emitting flames and hurling enormous masses of rock into the adjoining valleys. The quay at Lisbon, upon which a great concourse of people had collected for safety, sunk in a moment, and not one of the persons upon it escaped. A great number of boats and vessels were swallowed in a whirlpool, no fragment of which ever rose again to the surface. The depth to which the quay sunk, was ascertained to be 100 fathoms. The earthquake was felt throughout nearly the whole of Europe, in Africa, and the West Indies. In Great Britain, rivers and lakes were agitated,—the waters of Lochlomond rose two feet, and then subsided below their usual level. It is calculated that the shock travelled at the rate of about 20 miles a minute. A great wave swept round the coast of Spain, where it rose 60 feet high. The same phenomenon, though to a less extent, was experienced at Madeira, and on the coast of Ireland.

In the summer of the present year, (1851,) Melfi, in the neighbourhood of Naples, so frequently the theatre of those terrible workings of nature, was visited by one of the most disastrous earthquakes of modern times. We quote the account given by an eye-witness, a medical officer, despatched by the Neapolitan Government to the scene of the earthquake in the upper Basilicata:—

"The village of Baville has actually disappeared. I found all about this district large fissures, partly filled up with houses. A man who escaped told me it appeared to him, that for a minute he was being tossed about in the air: the earth appeared, as it were, endowed with a breathing power, and then came a different movement—a shaking to and fro. Here some military had arrived to excavate. There was a strong stench of decomposing bodies. This place was really deserted by the inhabitants; at least, I saw very few. How shall I give you an idea of what was once the town of Melfi? The cathedral is down, as are the college, the churches, the military depot, and 163 houses—98 are in a falling state, and 180 pronounced as dangerous. The military have arrived, and are working away. Our medical staff is by no means strong enough. More than a thousand bodies have already been dug up; I need not add, all dead. The wounded are over 600, and present every variety of flesh-wounds and fracture. Sixty-five boys of the college of Melfi are supposed to have perished. The calamity took place when most of the population were sleeping, as is the custom in Italy after dinner."

At the Police Office in Naples, on the 27th August, they replied to inquiries—"Up to this day the returns of dead bodies, dug out of the ruins from all towns and villages, is 857; but the excavations have only commenced."

Much more might be cited to show the devastation wrought by earthquakes, and their effects in producing changes in the configuration of the districts in which they occur; but enough has been adduced to satisfy the reader, that there resides in the interior parts of the earth,—agencies, which when awakened, are capable of producing all that alteration with which we are impressed, as having taken place in almost every geological epoch, when we survey the shattered, twisted, and contorted condition of the rocks which compose the crust of the earth.

ANATOMY AND PHYSIOLOGY.

CHAPTER VIII.

THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

The muscular system, like other parts of the body, possesses the faculty of conservation and self-reparation. When a muscle is exhausted and lacerated, the circulating blood deposits the necessary elements to preserve and repair it. A muscle has the inherent power of applying the elements of the blood to the renovation of its substance, and the reparation of its injuries; and in a state of healthy action, easily effects the conservation, and restores the integrity of its lacerated parts.

During the juvenile growth of the muscles, the same animal law is established for their enlargement that in old age is required to preserve them from decay. In both cases, the circulating blood supplies the necessary elements for growth and preservation. The order, promptitude, and facility with which the muscles perform their vital functions, and extract from the blood the individual elements only that are required for their necessities, is one of the unanswerable arguments, that the Author of our existence is not only an infinitely powerful, but a provident Being.

The muscles, like other animal substances, are liable to diseases that sometimes require the aid of operative surgery. Surgical operations reflect very little honour on the art of healing; because they prove that the healing art is still imperfect. If it were perfect, there would be no necessity for operative surgery; yet sometimes, great operative surgeons appear to be prouder of having successfully performed a great operation, than of having accomplished the cure of a morbid disease by the materia medica. The cure of a morbid disease reflects more honour on the healing art, than the successful performance of a great operation. Sometimes we might almost be tempted to conclude, that the end and aim of the great operative surgical mania, is to ascertain *secundum artem*, with how little of his *corpus* a human being may be made to exist. Yet when the healing art pronounces a cure impossible, there is no other alternative even for the most humane surgeon, than to operate; and it is better to part with an incurable morbid portion of the body, and preserve life, than permit it to remain and destroy our existence.

Some men have large powerful muscles; others puny and weak. There are fixed animal laws that regulate their growth and preservation; and by obeying them, any person may attain the muscular maximum that belongs to his constitution. The hardy mountaineer climbs his native hill with vigour, elasticity, and ease, chases the nimble goat, and pursues the bounding deer, unfatigued for a long summer's day. The delicate lady, confined to the city, and nursed in effeminacy, pants for breath when travelling on the green lawn after half an hour's Lilliputian journey. The too early confinement of children at school, super-exercises and injures their brain, and renders their muscles puny and debilitated. The muscles of the hardy peasant child, accustomed to exercise, are larger and more powerful than those of the less fortunate girl confined to factory labour. Children should be allowed the free exercise of their muscles, if we would

have them enjoy health and become robust. Disease and death destroy more children and adults in large cities, than in rural districts. Dr Farr states, that out of equal proportions of English inhabitants, in a given time, 47 die in cities, and 29 in the country. One-half of all the deaths in Glasgow, during the last ten years, were children under five years old. These are appalling facts, and humanity demands an immediate legislative remedy for the prevention of this human destruction. If mechanical and agricultural labour were usefully combined; and if the population were more extended over the country, instead of being pent up into large overcrowded cities, the *muscles* of the population would speedily attain their due development, and death would ensue only from natural causes.

Unless the body be regularly supplied with plenty of nutrient diet, the muscles will lose their vigour and soon decay. There is a continual waste going on. To supply the carbon for respiration during a day, supposing that the individual takes moderate exercise, and throws off 8 oz. of that element in the form of carbonic acid, he requires 18 oz. of starch, which is equivalent to $1\frac{3}{4}$ lbs. of wheaten bread, or $7\frac{1}{2}$ lbs. of potatoes; and to repair the waste of his muscular system, he requires during the same time to assimilate from his food not less than 350 grains of nitrogen, that is, as much nitrogen as is contained in 5 oz. of gluten or fibrin. Now $1\frac{3}{4}$ lbs. of bread contain 3 oz. of gluten, and $7\frac{1}{2}$ lbs. of potatoes contain $2\frac{1}{2}$ oz. of that constituent; in the one case there therefore remains to be supplied 2 oz., and in the other, $2\frac{1}{2}$ oz. of gluten; and suppose the deficiency to be made up with beef; 8 oz. with $1\frac{3}{4}$ lbs. of bread, or 10 oz. with $7\frac{1}{2}$ lbs. of potatoes, are the calculated quantities of diet which are essential to the maintenance of the animal system in a healthy state. If a man would attempt to live on bread alone, he ought to consume 3 lbs. per day; in the case of potatoes, no less than 15 lbs. I shall now proceed to the muscles of the lower extremities.

The muscles that move the thigh bone are the 14 following: 1st, Tensor vaginæ femoris; 2d, Psoas magnus; 3d, Psoas parvus; 4th, Iliacus internus; 5th, Pectinalis; and 6th, The Triceps femoris, which is subdivided into the three following branches; viz., Adductor longus, adductor brevis, and adductor magnus. These six muscles move the thigh forward, point the toes inward, and are inserted as follows:—The Psoas magnus and Iliacus internus, into the trochanter major of the thigh bone, and the pectinalis and triceps into the linea aspera. The first three of the remainder of these fourteen muscles are; 7th, The Glutæus maximus; 8th, Glutæus medius; and 9th, The Glutæus minimus. These three move the thigh-bone backward and outward, and are inserted as follows:—The Glutæus maximus into the linea aspera; the Glutæus medius into the trochanter major, and Glutæus minimus into the top of the trochanter. The remaining five muscles are; 10th, The Obturator externus; 11th, The Gemini, which some anatomists subdivide into two; 12th, The Obturator internus; 13th, The Quadratus femoris; and 14th, The Pyriformis. These five move the thigh-bone backward, roll it on its axis, and are also inserted as follows:—The Obturatores externus and internus, the pyriformis and gemini into the root of the trochanter and the quadratus, betwixt the trochanters. These fourteen large fleshy muscles (*in toto*) assist in forming the contour of the thigh, and perform many of its most powerful and useful actions.

There are four muscles that extend the leg:—1st, The Rectus femoris; 2d, Cruræus; 3d, Vastus internus; and 4th, Vastus externus. These large muscles assist in forming the thigh, and are all implanted by one strong tendon into the patella, or knee-lid. But the vastus externus and internus also send some fibres to be inserted on the outer part of the head of the tibia or great bone of the leg,—the knee being a hinge-joint, these four muscles extend the leg, bend the thigh on the trunk, and are the great agents in running, leaping, and walking. There are six Flexor muscles that bend the leg:—1st, The Sartorius, or Tailor's muscle, by which the legs are crossed; 2d, Gracilis; 3d, Semitendinosus; 4th, Semimembranosus; 5th, Poplitæus; and 6th, Biceps cruris. The first four are inside flexors, and their tendons are inserted into the rough head of the tibia, or large bone of the leg; they also form the hamstrings, and extend their aponeurotic expansions downward upon the leg. The tendon of the biceps is implanted into the upper knob of the fibula, or small bone of the leg, and the poplitæus is inserted broad into a ridge on the back part of the tibia. These muscles form part of the fleshy and tendinous substance of the ham and thigh. There are six Extensor muscles of the foot; the first four, viz., 1st, The gastrocnemius; 2d, The plantaris; 3d, The solæus; and 4th, Tibialis posticus, lie on the back part of the leg; and the last two, viz., 5th, The perinæus longus; and 6th, perinæus brevis, lie on the outside of the leg. These extensor muscles are useful in running, walking, and leaping. There are also two flexor muscles of the foot, that bend it when acting together, lying on the fore part of the leg, viz., the tibialis anticus, and the perinæus tertius. The tendon of Achilles, (or the thick cord which is attached to the heel-bone, and forms the inferior posterior portion of the leg,) is formed by the union of the solæus and gastrocnemius muscles. There are sixteen muscles of the toes that move them in every direction,—their names generally denote their uses: flexion, extension, abduction, and adduction, are performed by their action. 1st, Flexor longus pollicis; 2d, Flexor longus digitorum pedis; 3d, Massa carnea; 4th, Flexor brevis digitorum; 5th, Lumbricalis; 6th, Extensor longus digitorum pedis; 7th, Extensor digitorum brevis; 8th, Extensor pollicis proprius, and the crucial ligaments; 9th, Abductor pollicis; 10th, Flexor brevis pollicis; 11th, Adductor pollicis; 12th, Transversalis pedis; 13th, Abductor minimi digiti; 14th, Flexor brevis minimi digiti; 15th, Interossei interni; 16th, Interossei externi, 17th, The plantaris aponeurosis is a thick aponeurotic expansion that defends the sole of the foot, and protects the blood-vessels, muscles and nerves, that lie under it from external injury. Sometimes contraction of the aponeurosis contracts the foot and deforms it. The toes are drawn inward and toward the sole of the foot, impeding its mechanical movements. The cure is accomplished by dividing the aponeurosis with a long thin knife nicely introduced underneath the skin. The foot is afterwards retained in a proper extended position, and subsequent inflammation prevented till it heals.

I was lately present when this simple operation was very adroitly performed on a boy, by an hospital surgeon. The aponeurosis of his foot was contracted, and also the tendo-Achilles. His toes were bent inward and downward, and his heel drawn upward and backward,—as soon as the aponeurosis and tendo-Achilles were divided, the foot partially resumed a natural position. A case of this kind requires a great deal of skilful management, even after the operation, and several weeks must elapse before it is cured.

Some of the French surgical authors inform us, that clubfoot contractions generally resume their original deformity, about four years after an operation. It would be desirable that the ultimate progress of such cases were also strictly watched by British surgeons, and reported to the profession. If the French authors are correct with these statements, it would not be very desirable for a patient to endure the operation, with the certainty of a relapse. I am aware that some cases of *squinting* partially corrected by recent surgical operations, have again resumed their original obliquity.

The flexors and extensors, the adductors and abductors of the toes, are antagonist muscles; the flexors bend the toes downward; the extensors raise them upward; the adductors draw them inward, and the abductors outward. And much in the same manner, the antagonists of the leg also act upon the foot, and move it by the ankle-joint in every possible direction. The mechanism of the leg and foot is beautiful and perfect, and nothing that science has invented can equal its beauty and utility. By the simple and combined action of a few bones and muscles, we climb, walk, run, leap, dance, &c., and perform tumbling and equestrian feats; without the muscles of the lower extremities, we should be obliged to stand immovable like statues, and vegetate like plants; yet aided by the simple, combined, and harmonious muscular machinery, we can move our joints at pleasure, and travel from place to place with agility and ease. By their powerful action, we climb the wild hills of Scotland and Wales—ascend the hoary Alps—mount the gigantic Andes, and overtop the almost insurmountable Himalayas. By their mechanical power we descend valleys, cross ravines, bogs, and marshes—traverse the sandy deserts of Africa, and the green prairies of America—parade through the richest kingdoms and capitals of the world, and visit the sublimest scenery of nature. The youthful, stout, active, and comfortable *pedestrian*, pursuing his voluntary journey without encumbering equipage in fine summer weather, and occasionally pausing on his

way, to admire the beauties of nature, and gaze on the relics of past ages, is the happiest and most independent of travellers; and as he cheerily passes along his road, trusting only to the powerful *muscles* of his lower extremities, to carry him to the end of his journey, he feels an elasticity of body, and a buoyancy of mind, indescribably pleasant; and as he exercises the active *muscles* of his limbs, and inhales the pure air, he imparts strength to the whole muscular system, and feels enjoyment that will delight him in his future years, with the sweetest reminiscences of the pleasures of the travels of the past.

The man who has never examined and studied the mechanism and functions of the *muscles* is apt to conclude, that the flesh is a solid mass, without any other use than to cover the bones, and constitute by its bulk, the external portion of the body. But when he minutely examines its anatomy and physiology, he perceives that it is mechanically constructed, and separated into long, broad, thin, layers; lying side by side, and above each other, and that each muscle is composed of long, slender fibres, each enclosed in its own cellular sheath; and that individually and combined, they perform every motion of the animal machine. It is the muscular system that chiefly distinguishes the activity of animals from vegetables, and gives the faculty of locomotion to the one, and immovability to the other. Yet some plants exhibit muscularity in a very limited extent. The sensitive plant shrinks its leaves from the touch of the human finger. The Venus fly-trap shuts its leaves on the insect that preys on the sweets of its bosom, and crushes it to death. The sunflower opens its bosom to the rising sun, and follows his course during day; and at night again closes its beautiful leaves, when the sun is absent. These are undoubtedly muscular actions, and, as far as they extend, are little inferior to the muscular motions of zoophites and some of the lowest tribes of animal existences. But the complete faculty of locomotion is denied them, and man and animals alone enjoy it in perfection. The creeping plants make the nearest approximation to the locomotion of animals.

On some parts of the body, particularly over the temporal muscles, the abdomen, the back, the arms, and thighs, a strong broad *fascial* membrane is spread over the muscles, to protect, cover, and give them firmness. This partial covering, by its gentle and powerful expansion, defends the internal parts from injury, and facilitates muscular motion.

When we thus look with philosophical minds into the great arcana of animated nature, and accurately comprehend it, we discover the *visible* presence of that *invisible* Being, who sits in mysterious silence behind the elements he has formed, and gives birth and movement to every atom.

We have now finished the muscles. The accompanying plates will enable the reader to determine their localities with accuracy. In the next essay we shall begin to describe the bones, and we may safely promise that the subject will become more interesting as we advance.

BIOGRAPHY.

THOMAS SIMPSON, F.R.S.

This very eminent mathematician was born at Market Bosworth, in the county of Leicester, the 20th of August, 1710. His father was a stuff-weaver in that town; and though in tolerable circumstances, yet, intending to bring up his son Thomas to his own business, he took so little care of his education, that he was only taught to read English. But nature had furnished him with talents and a genius for far other pursuits, and which led him afterwards to the highest rank in the mathematical and philosophical sciences.

Young Simpson very soon gave indications of his turn for study in general, by eagerly reading all books he could meet with, teaching himself to write, and embracing every opportunity he could find of deriving knowledge from other persons. His father observing him thus to neglect his business, by spending his time in reading what he thought useless books, and following other similar pursuits, used all his endeavours to check such proceedings, and to induce him to follow his profession with steadiness and better effect. And after many struggles for this purpose, the differences thus produced between them at length rose to such a height, that young Simpson quitted his father's house to seek a home for himself.

On this occasion he repaired to Nuneaton, a town at a small distance from Bosworth, where he went to lodge at the house of a tailor's widow, of the name of Swinfield, who had been left with two children, a daughter and a son, by her husband, of whom the son, who was the younger, being but about two years older than Simpson, had become his intimate friend and companion. And here he continued some time, working at his trade, and improving his knowledge by reading such books as he could procure.

Among several other circumstances which, long before this, gave occasion to show our author's early thirst for knowledge, as well as proving a fresh incitement to acquire it, was that of a solar eclipse, which took place on the 11th day of May, 1724. This phenomenon, so awful to many who are ignorant of the cause of it, struck the mind of young Simpson with a strong curiosity to discover the reason of it, and to be able to predict the like surprising events. It was, however, several years before he could obtain his desire, which at length was gratified by the following accident. After he had been some time at Mrs Swinfield's at Nuneaton, a travelling pedlar came that way, and took a lodging at the same house, according to his usual custom. This man, to his profession of an itinerant merchant, had joined the more profitable one of a fortuneteller, which he performed by means of judicial astrology. Every one knows with what regard persons of such a cast were treated by the inhabitants of country villages; it cannot be surprising, therefore, that an untutored lad of 19 should look upon this man as a prodigy, and, regarding him in this light, should endeavour to ingratiate himself into his favour; in this he succeeded so well, that the sage was no less taken with the quick natural parts and genius of his new acquaintance. The pedlar, intending a journey to Bristol fair, left in the hands of yonng Simpson an old edition of Cocker's Arithmetic, to which was subjoined, a short appendix on Algebra, and a book upon Genitures, by Partridge the almanac-maker. These books he had perused to so good purpose, during the absence of his friend, as to excite his amazement upon his return; in consequence of which he set himself about erecting a genethliacal figure, in order to a presage of Thomas' future fortune.

This position of the heavens having been maturely considered, *secundum artem*, the wizard with great confidence pronounced, that, "within two years' time, Simpson would turn out a greater man than himself!"

In fact, our author profited so well by the encouragement and assistance of the pedlar, afforded him from time to time when he occasionally came to Nuneaton, that, by the advice of his friend, he at length made an open profession of casting nativities himself; from which, together with teaching an evening school, he derived a pretty pittance; so that he greatly neglected his weaving, to which indeed he had never manifested any great attachment, and soon became the oracle of Nuneaton, Bosworth, and the environs. Scarce a courtship advanced to a match, or a bargain to a sale, without previously consulting the infallible Simpson about the consequences. But as to helping the people to stolen goods, he always declared that above his skill; and over life and death he declared he had no power: all those called lawful questions he readily resolved, providing the persons were certain as to the horary data of the horoscope; and, he has often declared, with such success, that if from very cogent reasons he had not been thoroughly convinced of the vain foundation and fallaciousness of his art, he never should have dropt it, as he afterwards found himself in conscience bound to do.

About this time he married the widow Swinfield, in whose house he lodged, though she was then almost old enough to be his grandmother, being upwards of fifty years of age. After this the family lived comfortably enough together for some short time, —Simpson occasionally working at his business as a weaver in the daytime, and teaching an evening school or telling fortunes at night; the family being also further assisted by the labours of young Swinfield, who had been brought up in the profession of his father.

But this tranquillity was soon interrupted, and our author driven at once from his home and the profession of astrology, by the fol-

the amount of atmospheric pressure upon him amounts to 14 tons. This he sustains without the slightest inconvenience; and the explanation is, that every cavity of his body is distended with aëriform matter of the same elastic force. The human structure may be regarded as a collection of open and close vessels, all of which are "packed in fluids." On the closed parts the pressure is equal inside and outside, and in case of such parts as are open, there is equilibrium between the internal and external air. Indeed, were it not for this same atmospheric pressure, which at first sight may seem an inconvenience, the finer vessels of the animal body would infallibly be ruptured and life destroyed, by the elasticity of the fluids within them. That we are able to move about under our atmospheric load, without being conscious of its existence, is owing to the equality of its action, and the perfect mobility of the particles through which it is transmitted; for, like all fluids, the gravity of air presses upward as well as downward, and laterally, and in every direction.

We have already remarked that the barometer is the bequest of Torricelli to science. This is essentially nothing more than a glass tube of about 33 inches long, with its open end placed in a cup of mercury. Water is sometimes employed, but the tube then requires to be about as many feet in length. The instrument is prepared thus:—First, fill the tube with the liquid, then having covered the open end with the finger, carefully invert it and place it under the surface of the mercury in the cup. Upon removing the finger the mercury will fall a certain distance, leaving a column in the tube of a height corresponding to the atmospheric pressure at the time. A scale being then attached, the instrument is complete.

Several modifications of the barometer are in use; but their theoretical action is the same as the straight tube barometer described, and none of them are better.

From causes which are not well understood, and which we cannot in the mean time wait to consider, the barometer informs us that the atmospheric pressure is not constant. At the equator, the mercury is at its maximum height at 9 o'clock in the morning,—past this hour it becomes less till 4 in the afternoon, when it reaches its minimum. It again ascends till 11 at night, when it reaches its second maximum, and once more descends till 4 in the morning, after which it reascends till 9. Thus, every day, the mercurial column is at its lowest elevation at 4 o'clock in the morning, and afternoon; and at its greatest, at 9 in the morning, and 11 in the evening. These periodic variations are small, being calculated at less than $\frac{1}{12}$ and more than $\frac{1}{13}$ of an inch by Humboldt; (namely, $\frac{7874}{100000}$ inch). In Europe, they are nearly obliterated by changes of atmospheric pressure depending upon accidental causes, which at the equator are nearly absent. It is upon these changes that we found the indications of the barometer as a weather-glass,—experience having pointed out that the weather is commonly fair and calm when the mercury is high, and wet and stormy when the mercury descends. As far as the horary variations can be observed in our northern latitudes, the maximum in winter appears to be at 9 in the morning; the minimum at 3 in the afternoon; and the second maximum at 9 in the evening. In the summer, the maximum elevations are at 8 in the morning, and 11 at night; the minimum being at 4 in the afternoon. In spring and autumn, the times of these variations are intermediate with those of summer and winter.—*Dr Golding Bird.*

As a column of 30 inches mercury answers to a pressure of 15 lbs. to the square inch, a fall of the mercurial column of an inch answers to a diminution of pressure of $\frac{1}{2}$ lb. on the square inch. Thus, if the barometric column stands at 29 inches, the atmospheric pressure is $14\frac{1}{2}$ lbs. instead of 15 lbs., and so on of all similar variations. There is, therefore, no difficulty in understanding why persons of weakly constitutions often feel considerable discomfort from sudden changes of the weather: the barometric oscillations which we experience in this country are considerable, often occasioning, in the course of a few hours, a change of pressure upon our bodies of not less than a ton weight.

We shall next direct attention to the chemical constitution of our atmosphere, and examine the subject a little more strictly.

ANATOMY AND PHYSIOLOGY.

CHAPTER IX.

THE BONES.

The important offices fulfilled by bone in the animal economy, and its almost imperishable nature, have always given it importance in the eyes of the philosopher; while the phrases in use in every language bear testimony to the high place it holds in popular estimation. We see it forming a frame-work to give shape and support to the body, cases and cages to protect the more delicate organs, and levers by which locomotion is performed, and force exerted. Again, we find it among the tombs, successfully resisting agencies which had reduced the softer parts of our bodies to dust a century before; and we speak of laying our bones in the grave as if they constituted the essential element of our frames.

In order to be fitted for the purposes above referred to, the bones, whose union constitutes the skeleton, are at once hard and tough; hard to resist external violence, and tough to give them a degree of elasticity. This hardness we shall find to depend on the large proportion of inorganic matter, especially of lime, which enters into the composition of bony tissue. This chemical constitution also accounts for its durability. Let us, in this article, devote our attention to what is called its *general* anatomy; that is to say, its physical properties, and chemical composition; its organization as a part of the living body, and any peculiarities that may appear worthy of the notice of the unprofessional reader.

The most remarkable property in bone, and that which first strikes us, is its great *hardness*, as compared with other parts of the body. It is, indeed, the only part of the body entitled to be called hard,—cartilage, which comes next to it, admitting of being cut with a knife. This hardness increases with old age, from the greater proportion of earthy matter which is deposited into its interstices, and it is much less in children of tender years. Its *specific gravity* is greater than that of any other animal substance. Its *colour* in the living body is a pale roseate tint, inclining in young children to red, and in old age to a yellowish white. It assumes a beautiful white colour after having been frequently boiled, or long steeped in water, till the oily and sanguine fluids which pervade it have been entirely removed. Bone is very feebly translucent,—even in thin plates transmitting only a slight quantity of light. It is, however, flexible and elastic. The ribs afford a good example of this, as any one may satisfy himself by compressing his chest with his two hands; and many a one has to thank this quality for his escaping with impunity from the pressure of a dense crowd. The elasticity of the bones frequently saves them from fracture, and lessens the shocks which they convey to the brain, and other soft textures which they support and defend.

Bones assume every variety of shape, as might be expected from the various uses made of them in such a complex machine as the skeleton. These varieties have been reduced by anatomists to four classes; the long or cylindrical, the broad or flat, the short or round, and the mixed or irregular. The long bones are distinguished by their length, which greatly exceeds their other dimensions. They are found only in the extremities, and are adapted for locomotion, and for sustaining the weight of the body. They are never exactly cylindrical, being smallest about the middle, and enlarged at each end where they are jointed to one another. The broad or flat bones are thin, and generally somewhat arched, being fitted to protect some more delicate organs; the best specimens of them are those forming the cranium, and protecting the brain. The short bones are of irregular figures, but are all somewhat roundish; they are found in the wrist, and the instep of the foot. The mixed or irregular bones are sometimes classed along with the short; but it is better to

place them separately. The bones forming the spine are the best examples of these, as combinations of long and short bones. The ribs, and bones of the pelvis, may, perhaps, be also arranged with them, as combining the characters of the long and flat.

We shall find that the different bones present points for demonstration of various kinds. They have surfaces which may be rough or smooth, for the attachment of the softer parts, or to allow these to play over them,—have hollows for the reception of muscles, or other organs,—they have grooves for tendons to run in, or for blood-vessels to lie in,—they have holes for vessels and nerves to pass through,—they have articular surfaces; rough if the joint is to be immoveable; smooth if it be to admit of motion; and they have *processes*, or projecting points, to which particular fibres, of muscle, or of ligament, are to be connected.

If we prepare bones by careful steeping and drying, so as to remove all the oily matter from out of them, and then saw them up, or break them, we shall observe the density of their tissue to differ much in different parts. The outer part is much harder and denser, than the internal part, and is called the compact substance. The internal part is of a looser texture, and is called the cancellated, (that is, cellular,) or spongy substance. These tissues are arranged differently in the different orders of bones.

In the flat bones, the compact substance is arranged into two layers, separated by a thin layer of cancellated structure, through which the blood-vessels which nourish the bone run. When the bone is very thin, the two outer layers are in contact, or appear compressed into one, and the intermediate layer has disappeared. In the round bones, there is a very thin layer of compact tissue on the outside, while the internal part is composed of spongy tissue. In consequence of this predominance of spongy tissue, and consequently of blood-vessels, the round bones are much more liable to inflammation than any of the others. The long bones consist of three parts—a shaft and two extremities. The shaft consists of very dense compact tissue externally, becoming loose internally, and having a canal running through it nearly from end to end; while the extremities are of the same structure with the short bones. This canal makes the bone much stronger than if it were solid, with the same quantity of material, because its diameter is thus much greater; a principle which is understood and acted on by engineers, who make hollow pillars and shafts to gain additional strength without additional expense of metal.

The canal which runs through the long bones is lined with a delicate membrane, in which is contained the medulla or marrow; hence it is called the medullary canal. The medulla is in the young chiefly bloody; in older persons it is oily; and it is put into the canals, not to oil the bones, as many erroneously suppose, but because there is no empty space permitted in the body, and fatty matter is the lightest that could be used for filling them. Besides, the marrow serves the same purpose as the fat in other parts of the body; it is a store of nourishment whence the body can be supported, when unable to take any nourishment from without. In fevers, for instance, when the patient scarcely tastes food for perhaps a fortnight or three weeks, he is maintained on the superfluous parts of his own body; and hence the sunken cheeks and shrunk shanks of such a sufferer when beginning to recover. That this marrow is not of any use to the bone itself is sufficiently proved by the fact, that in birds there is none; but their bones are very thin, and the canals large in order to be light, and instead of marrow they are filled with air, by communications with the windpipe leading to the lungs. There is a common notion that the marrow is exceedingly sensible, and it is remarked "how painful the application of the saw must be in amputation, from its tearing its way through the marrow." Now, the fact is, that the marrow is very little, if at all sensible; and all the pain felt in sawing the bone is a sort of jarring communicated to the soft parts which have been already divided.

The irregular bones, resembling in shape two or more of the preceding orders, have some of their parts, generally their bodies, resembling the round bones; and others, the processes, resembling the long and flat.

The animal and earthy parts of bone can be easily separated, and demonstrated in a separate state. If a piece of bone be immersed for a day or two in diluted muriatic (hydrochloric) acid, the earthy part will be completely dissolved out, and the animal part will be left; yet the bone will still have the same size and the same shape,—so intimately are the two different materials blended together. If it be now dried and weighed, it will be found to have lost nearly two-thirds of its original weight—the loss consisting of the earthy particles. The substance now obtained is the cartilage of bone, which is very nearly the same in composition as the cartilage which we find in the body, ready formed by nature. It is much softer than bone, but harder than any other of the soft parts; it is highly elastic, and if compressed or bent, speedily regains its original shape. When dried, it assumes a darker colour, and becomes hard and tough, translucent, and very like horn. When boiled, this substance is nearly all dissolved, yielding a fine transparent jelly; and it was a knowledge of this property which suggested to Papin the invention of his digester, in which, by boiling bruised bones under strong pressure, the jelly is obtained, and a large quantity of strong soup is made from what would otherwise be entirely worthless. The earthy part of the bone is demonstrated in a different manner. If a bone be put into a clear fire, and heated to redness, the animal part is entirely consumed, and a white friable earth is left behind. This earth consists almost wholly of lime, in combination with phosphoric and carbonic acids. It is on account of their containing the former acid, that phosphorus is obtained from calcined bones. There are minute portions of other salts in the earthy part of bone, but these need only be named in a subsequent table. When a bone has been thus burned, and is weighed, it will be found above one-third lighter than at first, the loss consisting of the gelatinous part. As was remarked of the gelatinous part when obtained by itself, so also the earthy part has exactly the original shape of the bone, and the most minute bony threads of the cancellated texture are still seen existing.

It was long believed that fat, or oil, was an essential part of bones, but that is now known not to be the case; for, the greasy appearance which bones are apt to have does not belong to themselves, but is the consequence of the marrow transuding through them after death.

The bones are covered by a dense membrane called the Periosteum, which adheres strongly to them, serves to convey the blood-vessels to them, and sends prolongations into all the little holes which exist in great number on their surfaces. It also serves as the medium for the attachment of tendons and ligaments to them, having those parts in a manner interwoven and confounded with its outer surface. The periosteum has also a considerable share in the growth of young bones, and in the reparation of old ones, when fractures or other injuries may have rendered that necessary.

When the bones touch one another, and are moveable, they are particularly smooth, and their surfaces are adapted to one another by corresponding prominences and concavities. In addition, to obviate friction they are covered at these places with what is called gristle, or cartilage. Cartilage is intermediate in hardness to bone, and what are properly called the soft parts—it is firm and resisting, and yet it has a great deal of elasticity. In some parts of the body there are cartilages serving for continuations to bones, such as those which continue the ribs, and connect them to the breast-bone, and they are exactly similar to bones from which the earthy part has been dissolved by an acid. But the cartilaginous crusts which cover the articular ends of bones are of a very beautiful and peculiar structure. If a piece of bone be sawn up towards its articular end, till all but cut through, and then the remaining part, and the cartilage covering it, be torn asunder, the cartilage will be found to present an infinity of fibres set perpendicularly on the surface of the bone. When a portion of bone with its articular cartilage has been macerated in water for some weeks, the cartilage is found to have lost its smooth surface and its cohesion, and looks exactly as if the bone had been covered with a bit of white velvet. It will now be obvious that, when pressure is made on the ends of the fibres, they yield by bending a little sideways, but are prevented from yielding much, by the closeness with which they are set together. In effect, the result is just what is seen on a larger scale, if the finger be pressed against the flat surface of a common clothes-brush, the bristles bending a little sideways, and so presenting an indentation on the surface.

As bones are living parts, they of necessity are provided with blood-vessels and nerves. On the surface of every bone may be remarked an infinity of minute pores, into which small blood-vessels run. If the surface of a bone be exposed by an injury in the living body, it will be seen to bleed, and it can be coloured artificially in the dead body, in a manner which will be explained

in the article on the circulation. This coloration, however, is practicable only in young subjects, where a great flow of blood takes place to the bones, to provide material for their growth; in adult years, when they have reached their full size, and have become hard and compact, much less blood, in proportion, circulates through them. There is another very curious way in which the vascularity of young bones can be demonstrated, by making the blood itself the vehicle of the colouring matter with which they are to be injected. If a young animal be fed for a fortnight or so, on food in which a proportion of chopped madder is mixed, the colouring principle of the madder will pass into its blood, arrive in its bones, and there chemically combine with the lime, tinging the bones of a beautiful rose-colour, which is permanent, even after the bones have been cleaned and well washed in pure water. The nerves which are distributed to bones are very trifling, so that in the healthy state they may be said to be almost insensible; but when they become inflamed, their sensibility is so much exalted, that the slightest touch causes excruciating agony.

The formation and growth of bones is an exceedingly interesting subject, but one that cannot well be studied except in the museum, where there are preserved abundant specimens of young children in every different period of fœtal life. In the fœtus, cartilage serves as a substitute for bone at first, and about the sixth week after conception, earthy matter begins to be deposited in it. In the flat bones it is at first deposited in the centre, and extends in lines radiating to the circumference, forming a delicate net-work like a bit of lace; and layer is superadded upon layer, until the necessary degree of thickness is obtained. In the round bones, ossification proceeds from the centre to the circumference. In the long bones, ossification commences at the middle of the shaft, and extends outward gradually to near the ends, when it stops. At a period soon after birth, the ends of the long bones begin to ossify separately, in their centres, in the same way that the short bones do, and they continue separated from the shafts of the bones by a layer of cartilage, till the 15th, 16th, or even the 18th year. Hence children should on no account be rudely pulled about, or twisted about the limbs; as the ends of the bones are apt to be thus twisted off—an accident which, if it do not occasion the loss of the limb, will at least produce incurable lameness.

The chemical composition of human bone, deprived of its blood, oil, and periosteum, is thus given with great minuteness by the celebrated Swedish chemist, Berzelius:—

Cartilage and gelatine (soluble in water),	32·17
Blood-vessels,	1·13
Fluoride of calcium,	2·00
Phosphate of lime,	51·04
Carbonate of lime,	11·30
Phosphate of magnesia,	1·16
Soda, with a very little muriate of soda and water,	1·20
	100·00

The account which has now been given of bone, as a tissue, is applicable, with trifling variations, not only to those of man, but of all the other mammalia, and of birds. In the arrangement of the bones, however, every species differs from the rest, according to the purposes which its body and limbs are intended to serve. The bones united in their places constitute the skeleton.

BIOGRAPHY.

LEONARD EULER.

Leonard Euler was one of the most celebrated mathematicians of the 18th, or perhaps of any other century. He was a native of Bale, and was born April 15, 1707. The years of his infancy were passed at Richen, where his father was minister. He was afterwards sent to the university of Bale; and as his memory was astonishingly retentive, and his application regular, he performed his academical tasks with great rapidity; and all the time that he saved by this was consecrated to the study of mathematics, which soon became his favourite science. The early progress he made in this branch of study, added fresh ardour to his application; by which he likewise obtained a distinguished mark of the attention and esteem of professor John Bernoulli, who was then one of the most eminent mathematicians in Europe.

In 1723, M. Euler took his degree as master of arts; and delivered on that occasion a Latin discourse, in which he drew a comparison between the philosophy of Newton and the Cartesian system, which was received with the greatest applause. At his father's desire, he next applied himself to the study of theology and the oriental languages; and though these studies were foreign to his predominant propensity, his success was considerable even in this respect: however, with his father's consent, he afterwards returned to mathematics as his principal object. In continuing to avail himself of the counsels and instructions of M. Bernoulli, he contracted an intimate friendship with his two sons, Nicholas and Daniel; and it was chiefly in consequence of these connexions that he afterwards became the principal ornament of the philosophical world.

The project of erecting an academy at Petersburg, which had been formed by Peter the Great, was executed by Catharine I.; and the two young Bernoullis being invited to Petersburg in 1725, promised Euler, who was desirous of following them, that they would use their endeavours to procure for him an advantageous settlement in that city. In the mean time, by their advice, he made close application to the study of philosophy, to which he made happy applications of his mathematical knowledge, in a dissertation on the nature and propagation of sound, and an answer to a prize question concerning the masting of ships; to which the Academy of Sciences adjudged the accessit, or second rank, in the year 1727. From this latter discourse, and other circumstances, it appears that Euler had very early embarked in the curious and useful study of naval architecture, which he afterward enriched with so many valuable discoveries. The study of mathematics and philosophy, however, did not solely engage his attention, as he in the mean time attended the medical and botanical lectures of the professors at Bale.

Euler's merit would have given him an easy admission to honourable preferment either in the magistracy or university of his native city, if both civil and academical honours had not been there distributed by lot. This being against him in a certain promotion, he left his country, set out for Petersburg, and was made joint professor with his countrymen Hermann and Daniel Bernoulli, in the university of that city.

At his first setting out in his new career, he enriched the academical collection with many memoirs, which excited a noble emulation between him and the Bernoullis; an emulation that always continued, without either degenerating into a selfish jealousy, or producing the least alteration in their friendship. It was at this time that he carried to new degrees of perfection the integral calculus, invented the calculation by sines, reduced analytical operations to a greater simplicity, and thus was enabled to throw new light on all the parts of mathematical science.

In 1730, Euler was promoted to the professorship of natural philosophy; and in 1733, he succeeded his friend D. Bernoulli in the mathematical chair. In 1735, a problem was proposed by the academy, which required expedition, and for the calculation of which some eminent mathematicians had demanded the space of some months. The problem was undertaken by Euler, who completed the calculation in three days, to the great astonishment of the academy: but the violent and laborious efforts that he made to accomplish it, threw him into a fever, that endangered his life, deprived him of the use of his right eye, and which afterwards brought on a total blindness.

The Academy of Sciences at Paris, which in 1738 had adjudged the prize to his memoir Concerning the Nature and Properties of Fire, proposed for the year 1740 the important subject of the Tides of the Sea—a problem whose solution comprehended the theory of the solar system, and required the most arduous calculations. Euler's solution of this question was adjudged a masterpiece of analysis and geometry; and it was more honourable for him to share the academical prize with such illustrious competitors as Maclaurin and Daniel Bernoulli, than to have carried it away from rivals of less magnitude. Seldom, if ever, did such a brilliant competition adorn the annals of the academy; and perhaps no subject, proposed by that learned body, was ever treated with such force of reasoning and accu-

racy of investigation, as that which here displayed the philosophical powers of this extraordinary triumvirate.

In the year 1741, Euler was invited to Berlin to direct and assist the academy that was there rising into fame. On this occasion he enriched the last volume of the Miscellanies (Melanges) of Berlin with five memoirs, which form an eminent, perhaps the principal, figure in that collection. These were followed, with amazing rapidity, by a great number of important researches, which are dispersed through the memoirs of the Prussian academy; a volume of which has been regularly published every year since its establishment in 1744. The labours of Euler will appear more particularly astonishing, when it is considered that, while he was enriching the academy of Berlin with a profusion of memoirs, on the deepest parts of mathematical science contained always under some new points of view, and often replete with sublime truths, and sometimes discoveries of great importance, he still continued his philosophical contributions to the Petersburg academy, whose memoirs display the marvellous fecundity of his genius.

In 1760, the Russian army, under General Tottenberg, penetrated into the Marche of Brandenburg, and pillaged a farm which Euler possessed near Charlottenberg. As soon as the Russian general was informed of the event, he immediately repaired the loss by a large sum; and, upon giving notice of the circumstance to the Empress Elizabeth, she added to the indemnity a present of 4000 florins. This act of generosity had, no doubt, a powerful effect in attaching Euler to the Russian government, which, notwithstanding his absence, had always paid him the pension which it granted him in 1742.

Having received an invitation from Catharine II., he obtained, in 1766, with considerable difficulty, permission from the king of Prussia to return to Petersburg, where he wished to pass the remainder of his days; but soon after his return, he was seized with a violent disorder, which ended in the total loss of his sight: a cataract, formed in his left eye, which had been essentially damaged by the loss of the other eye, and too close an application to study, deprived him entirely of the use of that organ. It was in this distressing situation that he dictated to his servant—a tailor's apprentice, who was absolutely devoid of mathematical knowledge—his Elements of Algebra; which, by their intrinsic merit in point of perspicuity and method, and the unhappy circumstances in which they were composed, have equally excited the wonder and applause of the learned. This work, though purely elementary, plainly exhibits the proofs of an inventive genius; and it is perhaps here alone that we meet with a complete theory of the Diophantine analysis.

About this time M. Euler was honoured by the Academy of Sciences at Paris with the place of one of the foreign members of that learned body; after which, the academical prize was adjudged to three of his memoirs, Concerning the Inequalities in the Motions of the Planets. The two prize questions proposed by the same Academy for 1770 and 1772, were designed to obtain from the labours of astronomers a more perfect Theory of the Moon. M. Euler, assisted by his eldest son, was a competitor for these prizes, and obtained them both. In this last memoir, he reserved for further consideration several inequalities of the moon's motion, which he could not determine in his first theory, on account of the complicated calculations in which the method he then employed had engaged him. He afterwards revised his whole theory, with the assistance of his son and Messrs Krafft and Lexell; and pursued his researches till he had constructed the new tables, which appeared, together with the great work, in 1772. Instead of confining himself, as before, to the fruitless integration of three differential equations of the second degree, which are furnished by mathematical principles, he reduced them to the three ordinates which determine the place of the moon: and he divided into classes all the inequalities of that planet, as far as they depend either on the elongation of the sun and moon, or on the eccentricity, or the parallax, or the inclination of the lunar orbit. All these means of investigation, employed with such art and dexterity as could only be expected from a genius of the first order, were attended with the greatest success; and it is impossible to observe without admiration, such immense calculations on the one hand, and on the other the ingenious methods employed by this great man to abridge them, and to facilitate their application to the real motion of the moon. But this admiration will become astonishment, when we consider at what period and in what circumstances all this was effected. It was when our author was totally blind, and, consequently, obliged to arrange all his computations by the sole powers of his memory and his genius: it was when he was embarrassed in his domestic affairs by a dreadful fire that had consumed great part of his substance, and forced him to quit a ruined house, every corner of which was known to him by habit, which in some measure supplied the want of sight. It was in these circumstances that Euler composed a work which alone was sufficient to render his name immortal.

Some time after this, the famous oculist Wentzell, by couching the cataract, restored sight to our author; but the joy produced by this operation was of short duration. Some instances of negligence on the part of his surgeons, and his own impatience to use an organ whose cure was not completely finished, deprived him a second time and for ever of his sight,—a relapse which was also accompanied with tormenting pain. With the assistance of his sons, however, and of Messrs Krafft and Lexell, he continued his labours: neither the infirmities of old age, the loss of his sight, nor the acuteness of the pain, could quell the ardour of his genius. He had engaged to furnish the Academy of Petersburg with as many memoirs as would be sufficient to complete its acts for 20 years after his death. In the space of 7 years he transmitted to the Academy above 70 memoirs; and above 200 more, left behind him, were revised and completed by a friend. Such of these memoirs as were of ancient date were separated from the rest, and form a collection that was published in the year 1783, under the title of Analytical Works.

The general knowledge of our author was more extensive than could well be expected, in one who had pursued, with such unremitting ardour, mathematics and astronomy as his favourite studies. He had made a very considerable progress in medical, botanical, and chemical science. What was still more extraordinary, he was an excellent scholar, and possessed in a high degree what is generally called erudition. He had attentively read the most eminent writers of ancient Rome; the civil and literary history of all ages and all nations was familiar to him; and foreigners, who were only acquainted with his works, were astonished to find in the conversation of a man, whose long life seemed solely occupied in mathematical and physical researches and discoveries, such an extensive acquaintance with the most interesting branches of literature. In this respect, no doubt, he was much indebted to a very uncommon memory, which seemed to retain every idea that was conveyed to it, either from reading or from meditation. He could repeat the Æneid of Virgil, from the beginning to the end, without hesitation, and indicate the first and last line of every page of the edition he used. He carried on his mind the most complicated calculations. With the design of instructing his grandchildren in the extraction of roots, he formed a table of the first six powers of all numbers up to 100, and he recollected them with the utmost accuracy.

Several attacks of vertigo, in the beginning of September, 1783, which did not prevent his computing the motions of the aerostatic globes, were however the forerunners of his mild passage out of this life. While he was amusing himself at tea with one of his grandchildren, he was struck with an apoplexy, which terminated his illustrious career at 76 years of age.

M. Euler's constitution was uncommonly strong and vigorous. His health was good; and the evening of his long life was calm and serene, sweetened by the fame that follows genius, the public esteem and respect that are never withheld from exemplary virtue, and several domestic comforts, which he was capable of feeling, and therefore deserved to enjoy.

The catalogue of his works has been printed in 50 pages, 14 of which contain the manuscript works.—The printed ones consist of works published separately, and works to be found in the memoirs of several Academies, viz., in 38 volumes of the Petersburg Acts (from 6 to 10 papers in each volume);—in several volumes of the Paris Acts;—in 26 volumes of the Berlin Acts (about 5 papers to each volume);—in the Acta Eruditorum, in 2 volumes;—in the Miscellanea Taurinensia;—in vol. 9 of the Society of Ulyssingue;—in the Ephemerides of Berlin;—in the Memoires de la Société Œconomique for 1766;—and in the Philos. Trans. by seven memoirs, from vol. 44 to vol. 62.

When we continue to observe a barometer in the same place, everybody knows that it does not remain stationary; but rises and falls. These changes are connected with the winds; accordingly, in the torrid zone where the winds are pretty regular, the rise and fall are trifling, amounting only to a few tenths of an inch. At Madras, for example, (north latitude 13° 4′ 8″.513), the variation is only 9·6 inches, and the greatest annual range ever observed in that place, was 0·664 inches, and the smallest 0·462 inches.

As we advance northward or southward from the equator, the range increases. In Glasgow, it amounts to 2·95 inches, and at St Petersburgh, it exceeds 3 inches.

It has been observed, that there are two periods of every day when the barometer is highest, and two corresponding periods in which it is lowest. These maximums and minimums are observed in all parts of the earth, nearly at the same time of the day, showing that they originate in tides of the atmosphere, occasioned by the action of the sun. The barometer is highest of all between nine and ten in the morning. It has another smaller maximum between ten and eleven at night. Its lowest points are between four and five in the evening, and four and five in the morning. These oscillations extend from the equator to latitude 64° 8′, beyond which point they have not yet been looked for: but they diminish in amount as the latitude increases.

The mean temperature of the air at the level of the sea is highest at the equator, and gradually sinks as we advance toward the poles. The mean temperature at the equator is 81°·5; in Antigua, 78·11; in latitude 45°, it is 56°. In Paris, (lat. 48° 49′) the mean temperature is 51°·48; in London, it is 50° or 51°; in Plymouth, 52°·08; in Glasgow 47°·75; in Edinburgh 47°·7. In Geneva, about 1640 feet above the level of the sea, and in latitude 46°20′, the mean temperature is 49°·55. In Victoria harbour, N. lat. 70°, it is 0°·82. The temperature at half-past nine in the morning is nearly the mean of the day.

The range of the thermometer increases with the latitude, and with the height above the sea

At Poona it is	53°·4 or from	40°·5	to 93°·9.
Paris,	76·2	23·4	to 99·6.
Berne,	119·25	—24	to 95·25.
St Petersburgh,	127·1	—35·7	to 91·4.
Victoria harbour, lat. 70°	130	60	to 70.

But in Great Britain this rule does not hold,—our heat and cold being both checked by the proximity of the sea. The greatest range of the thermometer in

London is	93° namely from	0°	to 93°
Glasgow is	84	0	to 84.

The atmosphere consists essentially of two distinct gaseous bodies, namely oxygen and azote. But besides these, it always contains a sensible quantity of carbonic acid gas; nor is it ever free, (at least in Europe,) from the vapour of water mixed with it in the gaseous state. Doubtless it contains also minute quantities of every gaseous body and of every vapour which is thrown into it from the surface of the earth, though (except in particular circumstances,) the amount of all of them besides the four first mentioned, is too small to be appreciable by our methods of investigation.

100 volumes of atmospheric air (supposing it freed from carbonic acid and moisture,) consist of 80 volumes of azotic, and 20 volumes of oxygen gases. These proportions, being constant on every part of the surface of the earth, have led to the notion that the oxygen and azote in the atmosphere are in a state of combination, and not merely mixed; but this by no means follows. For the supply of atmospherical air is so vast, that if we were to suppose a thousand millions of animals constantly breathing it for six thousand years, and converting oxygen into carbonic acid gas, and if we were to double this consumption of oxygen, for the fires that are continually burning in all parts of the earth, it would not make an appreciable alteration in the ratio of oxygen to azote.

1. Oxygen is a gaseous body which is invisible and destitute of colour, taste, and smell. Its specific gravity is 1·1111, that of air being 1. One hundred cubic inches of it at 32° weigh 36·4330 grains. It is essential to the existence of all animals, being absorbed in the lungs, and partly converted into carbonic acid. When animals are made to breathe a determinate quantity of common air, the oxygen gas in it is gradually diminished, and converted into carbonic acid; and when this change has proceeded a certain length, the animal dies of suffocation. The same thing happens when the animal is made to breathe oxygen gas instead of air. But in oxygen gas, he lives nearly twenty times as long as in the same bulk of atmospherical air.

The oxygen of the air also supports combustion. The common combustibles are chiefly compounds, carbon and hydrogen. During combustion, they combine with the oxygen of the atmosphere, and are converted into carbonic acid and water. Thus, combustion and the breathing of animals constantly diminish the oxygen of the air, and in process of time would no doubt absorb the whole, were it not that new oxygen is constantly thrown into the atmosphere by the vegetation of plants. Thus, the functions of animals and vegetables counteract each other. Animals are constantly diminishing the oxygen, and increasing the quantity of carbonic acid in the atmosphere. Plants, on the other hand, are constantly absorbing the carbonic acid thus formed, decomposing it, retaining the carbon and giving out the oxygen. These two opposite processes no doubt counterbalance each other, and thus the oxygen of the air does not diminish, nor the carbonic acid increase.

2. The *azotic* or *nitrogen* gas constitutes four-fifths of atmospheric air. Like oxygen it is colourless, invisible, and destitute of taste and smell. Its specific gravity is 0·9722, that of air being 1. One hundred cubic inches of it at 32° weigh 31·8790 grains. It is not sensibly absorbed by animals nor by plants, nor does it support combustion. No animal can breathe it without suffocation; but it qualifies the stimulating property of oxygen gas. When an animal breathes oxygen gas, the heat is increased, and the circulation accelerated, and a feverish state comes on, which speedily destroys the animal. The admixture of azote prevents these injurious effects, and preserves the animal in a state of health.

Azote constitutes a part of the system both of animals and vegetables. In animals the azote which they contain is derived from the food which they eat. It is not so easy to see the origin of it in vegetables. But there can be no doubt that the azote of the atmosphere is employed in the formation of nitric acid,* and that this nitric acid, after it has been generated, is in various processes converted into ammonia.† It is probably from one or other of these two sources, that the vegetables derive the azote which they contain. These, in their turn, supply animals with that necessary article; and doubtless, during the putrefaction of animal substances, the azote thus absorbed is again given out, and thus its quantity in atmospherical air remains unaltered.

3. Carbonic acid gas, the third constituent of the atmosphere, constitutes rather less than $\frac{1}{1000}$th of its volume. It is colourless and invisible; but neither destitute of taste nor smell. Its taste is decidedly sour, and it impresses on the nostrils that sensation which is observed when a bottle of brisk ale, or of champaign just drawn, is applied to them. Its specific gravity is 1·5277, or it is rather more than $1\frac{1}{2}$ times that of common air. One hundred cubic inches of it at the temperature of 32° weigh 49·9780 grains. No animal can breathe this gas, and it immediately extinguishes a candle. Indeed a candle will not burn in a mixture of nine parts of air, and one part of carbonic acid; so that the atmosphere would become unfit for the respiration of animals, and the combustion of fuel, if it contained the tenth part of its bulk of carbonic acid gas.

Carbonic acid gas is constantly forming by the processes of breathing and combustion; yet its quantity never undergoes any sensible increase. Every individual, at an average, by breathing, throws 272 cubic feet of carbonic acid gas into the atmosphere in 24 hours. If we suppose the population of Glasgow to be 350,000, the quantity of carbonic acid gas, thrown daily into the atmosphere by 350,000 human beings, would be 95,200,000 cubic feet. If we admit the other animals, horses, cows, dogs, cats, birds, &c., to amount to $\frac{1}{10}$th of 350,000, they would produce about 10,800,000 cubic feet more;‡ so that the whole carbonic acid thrown into the atmosphere in Glasgow by breathing, in 24 hours, must amount to 106,000,000 cubic feet.

If we suppose the consumption of coals in Glasgow and the neighbourhood to amount daily to 3000 tons, this will produce 1,438,013 cubic feet of carbonic acid gas. Thus, the whole of

* Composed of nitrogen and oxygen.

† Composed of nitrogen and hydrogen.

‡ This estimate must be greately under the truth. A cow in 24 hours throws into the atmosphere, by breathing, five times as much carbonic acid as a man does.

that gas thrown daily into the atmosphere in Glasgow, cannot be less than 120,000,000 cubic feet.

Every volume of carbonic acid gas produced renders five volumes of air unfit for respiration. Hence, in 24 hours, 439,385,100 cubic feet of air are rendered unfit for respiration, or in fact poisonous.

Now, a base of four square miles, with a height of 100 feet, contains 44,605,000,000 cubic feet, of which 8,921,000,000 are oxygen gas. Consequently, in little more than 117 days, the whole oxygen in that space would be converted into carbonic acid gas, and every living being in Glasgow and its environs would be destroyed. Yet if we examine the atmosphere in Glasgow or its neighbourhood, we find it always to contain the usual volume of oxygen gas, and the proportion of carbonic acid gas never exceeds $\frac{1}{1000}$th of the volume of the atmosphere.

This is a most important circumstance, upon which the healthiness of cities entirely depends. It is owing to a property which gases possess. Every gas is composed of particles which repel each other; but the particles of one gas do not repel those of another. The particles of oxygen gas repel the particles of oxygen gas; and in like manner the particles of carbonic acid gas repel those of carbonic acid gas; but a particle of oxygen gas does not repel a particle of carbonic acid gas. The consequence of this property is, that every gas diffuses itself equably through the whole atmosphere. The carbonic acid gas, formed in Glasgow and its neighbourhood, does not remain in Glasgow, but diffuses itself equably through the whole atmosphere; and the atmosphere is so vast, that this quantity of carbonic acid gas, and millions of millions more, from other towns and cities, have no sensible effect in increasing the volume of that gas; its quantity is also kept down by its absorption and decomposition by plants, which replace the oxygen as it is withdrawn, and prevent the ratios of the constituents of the atmosphere from changing much.

4. The fourth constituent of the atmosphere is the vapour of water. It varies much more in its proportions than any of the other constituents. It is well known that water evaporates at every temperature from zero to the boiling point, and that the rate of evaporation increases with the temperature. This evaporation is entirely confined to the surface, and is therefore proportional to the surface. It is promoted by wind, and increased by heat. If the quantity evaporated per minute from a given surface of water, at the temperature of 18°·5, be represented by 2, the increase of evaporation as the temperature augments is shown by the following table:—

Temp.	Rate of evaporation.	Temp.	Rate of evaporation.
18°·5	2	125°	64
38	4	150	128
58	8	180	256
79·5	16	212	512
100	32		

So that if we fill a pan with water, and raise its temperature to 100°, it will take 16 times as long to evaporate, as it would do if heated to 212°.

When water evaporates, it is converted into an elastic fluid, invisible likewise, and destitute both of taste and smell. But its specific gravity and its elasticity increase with the temperature. At 212° its elasticity is the same as that of common air,—hence the reason why water boils at that temperature. It is called *steam* at that temperature, and its specific gravity is 0·625, that of air being 1. If we force the particles of steam nearer each other than when they possess just the elasticity of the atmosphere, they give out heat, and are partly or wholly converted into water, according to the degree of pressure. The elasticity of vapour diminishes with the temperature. This elasticity is measured by height, which its pressure produces on a column of mercury in a barometrical tube. At 212° this height amounts to 30 inches; at 180° it amounts to 15 inches; at 150° to 7·5 inches; at 125° to 3·75 inches; at 100° to 1.875 inches, and so on.

The quantity of vapour capable of existing in the atmosphere depends upon the temperature. How much is present at any time is easily ascertained by determining the temperature at which moisture is condensed, upon the external surface of a glass tumbler exposed to the air. If moisture be condensed on the tumbler when of the same temperature with the air, then the atmosphere contains as much moisture as it can contain at that temperature. Such is the case sometimes in this country, and it is indicated by the circumstance, that when wet clothes are hung out to dry, they retain their moisture because the water with which they are wet cannot evaporate. Should the tumbler remain dry, as will generally be the case, we must cool it by filling it with water colder than the air. This, in summer, is easily got from wells or deep springs. In winter, we must cool the water with ice, or by a mixture of snow and salt. By allowing the cooled tumbler to heat, till water just ceases to be condensed on it, and noting the temperature, we have the point indicating the elasticity of the vapour of water in the atmosphere.

Dr Dalton drew up, many years ago, a table showing this elasticity at every temperature. The following table shows a few of these elasticities.

Temp.	Force of vap. in in. of mercury.	Temp.	Force of vap. in in. of mercury.
32°	0·2	60	0·52
40	0·26	70	0·726
50	0·36	80	1·012

Many experiments have been made in this way in different places, to determine the quantity of vapour in the atmosphere in different parts of the earth. In Glasgow the greatest quantity of vapour exists in the atmosphere, in the month of August. The mean dew point (as the point at which moisture begins to condense on the tumbler is called,) is 50°, indicating an elasticity of 0·3766 inch. This amounts to about $\frac{1}{80}$th of the volume of the atmosphere. The smallest quanity is usually in the month of February, when the dew point is between 36° and 37°, indicating an elasticity of vapour amounting to 0·2314 inch: this amounts to nearly $\frac{1}{130}$th of the volume of the atmosphere. But though the volume of vapour in August be much greater than in February, the atmosphere is drier in the former month than the latter because the dew point, 50°, is at a greater distance from the mean temperature of the month, than 36° is below the mean temperature of February.

In some parts of the west coast of Africa, and in India, the atmosphere seems sometimes to contain no vapour, or very little. The mean dew point in Antigua, during July, August, and September, is 74°·43. The highest dew point observed by Col. Sykes, in the Deccan, was 76°. The mean dew point was 60°·74, and the mean temperature 78°·5. Thus, the air in India, though containing $\frac{1}{50}$ of its volume of vapour, is much denser than in Glasgow.

ANATOMY AND PHYSIOLOGY.

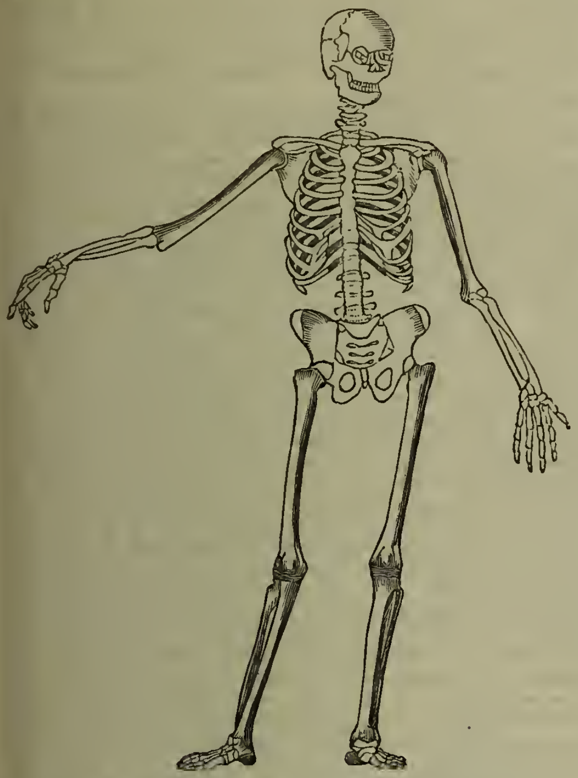
CHAPTER X.

THE SKELETON.

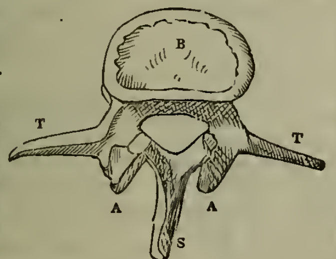
The Skeleton consists of the head, the trunk, and the extremities. No explanation is needed to define the limits of the head. The trunk is composed of the spine, the ribs, the breast-bone, and the pelvis; supporting the head upon its upper end, and resting its lower end on the heads of the thigh-bones. The extremities are four—two superior, commonly called in man, the arms; and two inferior, commonly called the legs; but, in strict anatomical language, the word leg is applied only to the part below the knee, the part above being always spoken of as the thigh; and only the part above the elbow is called the arm, the part below being the fore-arm. We shall now examine these parts in succession more minutely.

The *Spine* is the central column, resting on the pelvis and thigh-bones, and supporting the chest, the head, and the superior extremities. It is about one-third of the length of the whole body; so that in a man who stands six feet high, the spine will be found about two feet long. It consists of twenty-four pieces, or *vertebræ*, named from the Latin word *vertere*, to turn, on account of their mobility. The largest is placed below, and they diminish gradually to near the top. Each vertebra is an irregular

bone in its structure, (see page 268,) and consists of a *body* and *processes;* the word process in anatomy signifying a projection



or prominence. The body of each vertebra is of the nature of a short bone, spongy in its texture, and very light. It is semicircular, or nearly so, being convex in front, and is flat above and below, where it supports and rests upon its neighbours. In the accompanying cut, B represents the body of the vertebra, with its upper flat surface turned toward the reader. From the back of the body, the arch of the vertebra is seen to spring, enclosing a space which is occupied by the spinal marrow. A couple of articular processes, A A, are seen, which receive a corresponding pair from the vertebra above, and two, similar to



these, are sent downward, to articulate with the one next below. Then, to serve as levers, for the purpose of bending and turning the spine, we have two transverse processes, T T, passing out on each side, and the spinous process, S, passing backward. These spinous processes form the chain of projections felt under the skin, which give the name to the whole column. The four-and-twenty vertebræ are joined together so as to allow of a little motion, and but a little, at any one joint, in order that the spinal marrow which passes down through the canal formed by the apposition of the different rings, may not be injured by too sudden a twist; but that the curves which it is obliged to form, in the various motions of the body, may be very gradual.

Even when at rest, the spine is not straight, but curved in three different places. First, it curves forward, where it rests on the pelvis, that it may not be exposed to too rough a shock, when we begin to move, from being in a state of rest. Secondly, it curves backward, in the region of the back, to increase the capacity of the chest, in which the heart and lungs are to be lodged. Thirdly, it curves forward again in the neck, in order to bring the weight of the head, which rests on it, over the point of support between the feet. Three regions are distinguished in the spine—the first, the cervical, or that of the neck, consisting of seven vertebræ; the second, or that of the back, consisting of twelve; and the third, or that of the loins, consisting of five. The vertebræ of the loins are the most moveable: it is here that the turning and bending of the trunk chiefly takes place, and, consequently, it is to this region that injuries are most apt to occur. Those of the neck are also very moveable, in order to allow of the head being turned in every direction, principally, it would seem, to extend, as much as possible, the sphere of vision.

To the twelve vertebræ of the back the ribs are attached—twelve on each side, in order to form the chest. On this account, they admit of but little motion on one another, because they, with the ribs and breast-bone, are to work together, as constituting, in a great measure, a single organ.

The *ribs* are long curved bones, convex externally, and concave internally. They get gradually longer from the first to the seventh, and from that shorter again to the twelfth. The ten upper ribs are connected to the breast-bone in front, by means of thin cartilages; which arrangement, it has been already remarked, gives elasticity to the walls of the chest. The lowest two, not being attached in front, are called the floating ribs. The heads of the ribs behind are connected to the vertebræ by a kind of hinge joint, which allows each rib to move up and down in the action of breathing. Each rib passes from its attachment, downward, outward, and forward; so that when lifted up by the muscles of inspiration, it at the same time is carried outward, and so enlarges, in both directions, the capacity of the chest.

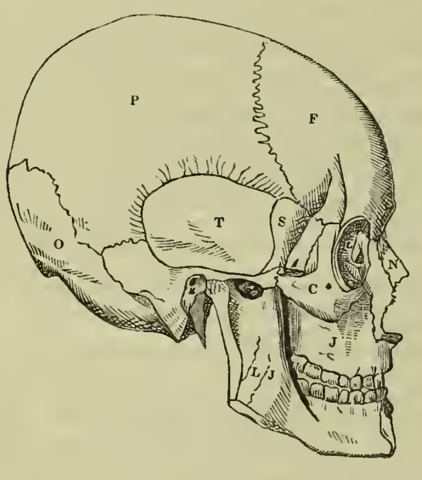
The *breast-bone* is about seven inches long, about two broad above, and one below, and ends in a moveable point formed of cartilage. It is smooth and convex in front, gives the prominence to the fore-part of the chest, and projects conspicuously in some individuals, who are thence commonly called "pigeon-breasted." It has the cartilages of the ribs inserted into its edges; it has a hollow in its upper part to make room for the wind-pipe to pass down behind it, and to its two upper corners the two collar-bones are attached.

The *Chest*, viewed as a whole, is conical—the apex of the cone being above, and the base below; the aperture above is small, measuring about four inches across, and two from before backward, allowing the wind-pipe and gullet, and the great veins of the arms and head to pass down, and their arteries to pass up. The inferior opening of the chest is large, and is filled by a muscle named the *diaphragm*, a Greek word, which literally means *the partition;* because it separates the belly from the chest, forming a roof for the one and a floor for the other. The chest is considerably deeper behind than in front, and the edges of the cartilages of the ribs can be felt, and, in a thin person, seen passing upward from the flanks, and meeting at an angle with the breast-bone, leaving a hollow between them, which is known as the pit of the stomach.

The *Pelvis* is so named because it is somewhat like a basin, only it has a wide aperture in the bottom, through which the canals from the bowels and the bladder, and in the female from the womb, make their exit. It consists of three distinct parts, the two haunch-bones, and the rump-bone. The last part sometimes receives the name of the false vertebræ—for in the young subject it consists of five pieces, which are real vertebræ—but in the adult these are firmly united into one, convex behind, and concave in front. It is of a triangular form, the base above, and the point below; and is terminated by two little pieces which do not make any projection externally, but are the same as those which, in greater number, constitute the tails of the lower animals. They are all that man possesses for a tail, or ever did possess,—all that Lord Monboddo has written to the contrary notwithstanding. The portions of the pelvis which form its sides are of a very irregular figure, expanded above on each side to form the projections of the haunches, narrow where they meet in front to form the part called the share-bone; having two knobs below, on which we sit, and two sockets below and towards the front, for receiving the heads of the thigh-bones. From the structure of the pelvis it will be understood, that it forms nearly a circle, possessing the strength of the double arch. The upper part of the arch has its abutments resting on the heads of the thigh-bones, and supports the spine upon its key-stone; while the reversed arch below binds the abutments together, and prevents their separation. The pelvis has another use, in forming the floor to the cavity of the belly, and so assisting to support its

contents, and yet another in giving origin to the powerful muscles which move the lower limbs.

The *Head* is placed upon the end of the spinal column, in order that the brain which is contained in it may be connected with the spinal marrow; and upon its upper end, that the eyes which are set in it may enjoy the widest possible range. It consists of two parts, the *cranium* and the *face;* the former for containing the brain; the latter for the organs of sight, smell, and taste. The *cranium* is very nearly of the shape of an egg, the larger end being backward, and the smaller one forward; presenting thus the characters, and having the strength of a double dome. The upper dome is however stronger than the lower one; and hence we find that when a man falls from a height on his head, the fracture is most frequently not at the part struck, but at the base, where it is completely out of the reach of the surgeon. The *face* cannot be compared to any known regular figure; it is excavated by several cavities, one large one for the mouth, another of considerable size for the nose, and two smaller pyramidal ones for the eyes, called the orbits. The number of bones in the head is twenty-two.



F. Frontal bone. O. Occipital bone. J. Upper jaw-bone. L. Lachrymal bone.
P. Parietal bone. S. Sphenoid bone. L. J. Lower jaw-bone. E. Hole leading into ear.
T. Temporal bone. C. Cheek-bone. N. Nasal bone.

The *Cranium* or brain-case is composed of eight bones, which are mostly of a flattened form, convex externally, and concave internally. The *frontal* bone forms the forehead, and the roofs of the orbits; the *occipital* bone forms the back and under part of the head, and in this bone is the large hole through which the spinal marrow passes down from the brain. The two *parietal* bones meet in the middle above, and form the upper and lateral parts of the head; in the centre of each is a protuberance giving the greatest breadth to the head, rather farther back than its middle. The *temporal* bones are named from the Latin word *tempus*, signifying time, because on the hair covering them, the traces of time are first manifested. They are placed one on each side, occupying the inferior lateral parts of the cranium, and extending into its base. In each is seen the funnel-shaped opening which admits the waves of the air to the drum of the ear, called the external auditory canal, to the edges of which the external ear is appended. The hard part of each, extending into the base of the cranium, contains the essential part of the organ of hearing. The two remaining bones are placed at the base of the cranium, and belong equally to it and to the face. The *æthmoid* or sieve-like bone is so named, on account of its upper plate being perforated with forty or fifty holes, through which the twigs of the olfactory nerves pass into the nose. A small part of it forms a portion of the inner boundary of the orbit, but this cannot be seen in the engraving. The *sphenoid*, or wedge-like bone is so named, not from any similarity to a wedge in shape, but from its being wedged in among so many other bones; for it is united to the other seven bones of the cranium, and to five of the face, all of which it in a great measure serves to bind together.

The vault of the cranium is smooth and regular, where it forms a roof for the protection of the brain; the floor of it is divided into six pits or deep hollows, for containing the different lobes of the brain. Numerous holes exist in the base of the cranium, for the entrauce of the nourishing arteries of the brain, for the exit of its veins, and for the passage of numerous nerves which are to connect the brain with the organs of the senses, and with the other parts of the body.

The *Face* consists of fourteen bones; six pair, and two single ones. The two *upper jaw-bones* form the principal part of the face. They meet in the middle line, forming the arch in which the upper row of teeth are set, and extend backward, forming the principal part of the roof of the mouth. A process runs up from each, separating the cavity of the nose from that of the orbit. In order that the face may be lighter, the body of the maxillary bone is not solid, but excavated,—the cavity communicating with the nose, as will be seen in the description of that organ. The roof of the mouth is completed by the two *palate-bones.* The firm part of the nose, from its roof to its bridge, is formed of two small pieces, meeting in the middle, called the *nasal bones.* These are liable to be broken, or knocked in, by a blow, an injury which occasions great disfigurement. The opening of the nose in front is seen in the skull to be of an oval figure, bounded by the two nasal and the two upper jaw-bones. Bounding the lower and outer parts of the orbits are the two *malar* or *cheek-bones*, making the prominences on the sides of the face, which are so marked in the races of Celtic origin. At the inner sides of the orbits are two little bones of the size and shape of the finger nail, called the *lachrymal bones*, because they form the chief part of the canals through which the tears find their way into the nose. Forming the partition of the nose, is a bone resembling a ploughshare in shape, whence its Latin name *vomer;* and in each side, within the nose, is a *spongy bone*, for the purpose of extending the olfactory surface. Finally, the *lower jaw* is a single bone, its dental arch equalling in size that formed by the upper jaw-bones, and containing as many teeth. The forepart of this bone is the chin, extending back from which, and gradually separating from each other, are its sides, which terminate at the angles, and from the angles the branches rise nearly perpendicularly upward, to be attached by moveable joints to the sockets in the two temporal bones.

Though composed of so many pieces, the whole head moves as one mass on the top of the spine; and the only motion that takes place between its parts, is the opening and closing of the mouth. This is done by the lower jaw dropping and being again lifted, while the upper jaw remains unmoved. This arrangement holds good in all beasts and birds; it is only when we descend to the reptiles and fishes, that we find both jaws moving, as in the crocodile and the shark.

The *orbits* are two cavities placed in the face, for containing the eyes. Each orbit is of a conical figure, the apex being behind, where the optic nerve enters it, and the base being in front; and it is much larger than is necessary for the size of the eye alone,—this delicate organ being cushioned on a quantity of soft fat, in order that it may move with the greatest ease in every direction. The inner walls of the orbits are parallel, while their outer walls diverge widely from one another, to give the eyes the advantage of as wide a range as possible, to accomplish which purpose we have seen that several provisions have already been made.

Tho *Lower Extremities* consist each of thirty bones. The *thigh* contains a single bone, the largest in the whole body. It has a long shaft, from which a neck goes off at an obtuse angle, surmounted by a smooth globular head, covered with cartilage, which is received into the socket that has been described as existing on the pelvis. Where the neck of the bone joins the shaft, there are two prominences which serve as levers for the attachment of strong muscles. The lower ends of the thigh-bones are large, and rest on the heads of the shin-bones. Their lower ends are much nearer one another than their upper ends, thus bringing the points of support underneath the weight of the body. The bones of the leg are two. The *shin-bone* is the inner and the larger, placed perpendicularly under the body,—it has a broad end above to articulate with the thigh-bone, and a smaller one below, to unite with the foot in the ankle-joint. One of its ridges is felt under the skin the whole way down, and is the part usually known as the shin. The outer slender bone, called the *fibula*, passes from the upper end of the shin-bone to the lower:

it is connected with the ankle-joint, but forms no part of the knee-joint; it has no connection with the thigh-bone, and therefore supports no part of the weight of the body. It serves to increase the breadth of the leg, without adding much to the weight, and is connected in its whole length to the shin-bone, by a strong membrane, or *interosseous ligament*, which serves to give attachment to muscles as well as if it had been bone, with the advantage of being much lighter. The lower ends of these two bones make the projections which are called the inner and outer ankles.

Intermediate to the thigh and leg is the *knee-pan*, a bone which corresponds to the elbow in the upper extremity. It glides on the smooth anterior part of the thigh-bone, is attached to the shin-bone by a strong ligament, and has the powerful extensor muscles of the leg inserted into it. It increases the power of these muscles, by throwing their attachment forward, and therefore farther from the centre of motion of the leg, thus conferring on them the advantage of a lever power.

The *Foot* consists of twenty-six bones. Seven of these form the *tarsus*, or solid part of the foot, to which no English word corresponds. Five compose the instep, or *metatarsus*, and the remaining fourteen are the joints of the toes. One of the bones of the *tarsus* is shaped above like a *pulley*, and is received between the projections of the two bones of the leg forming the two ankles, so that by its motion the foot is bent up at right angles to the leg, or pointed with the toes downward. The *bone of the heel* projects nearly an inch and-a-half backward, giving a strong lever for the insertion of the powerful muscles which form the calf of the leg. The next bone is in front of the pulley-like bone, and in some persons is very moveable, admitting of much lateral motion across the middle of the foot. Three *wedge-shaped*, and one *cuboid* bone, in front of these, complete the *tarsus*, and support the instep. The five bones of the *metatarsus* are each about two inches and-a-half long; they are attached posteriorly to the solid part of the foot, and anteriorly they support the toes. Their anterior ends rest upon the ground in standing, so that the foot presents an arch—the end of the heel-bone behind, and the ends of the metatarsal bones in front, being the abutments, while the pulley-like bone is the keystone on which the weight of the body rests. (See figure of skeleton.) This arch is not, however, firm or rigid, but yields a little when leant on; and to prevent its yielding too much, is strengthened below with strong ligaments, passing like a bow-string from behind forward. The degree of hollowness is very different in different persons, and those in whom it is most developed are always the most active, and the best pedestrians. The foot is arched also from side to side; and in the hollow thus gained, the blood-vessels, nerves, and tendons, going to the toes, lie secure from injury by pressure. The metatarsal bone of the great toe is much stronger than that of any of the others. To this toe there are only two moveable pieces, much larger than the joints of the other two. Each of the smaller toes has three pieces, similar to the joints of the fingers, but much smaller, as they are not intended for laying hold with. The last piece is enlarged towards its point, for supporting the nail on its upper, and the pulpy extremity of the toe on its lower surface.

The above figure represents the upper surface of right foot. P, pulley-shaped bone. H, heel-bone. N, navicular or boat-shaped bone. 1, 2, 3, first, second, and third, wedge-shaped bones. C, cuboid bone. 5, the five metatarsal bones. J, moveable joints of toes.

MECHANICS.

PART I.—STATICS.

CHAPTER II.

THE LAWS OF EQUILIBRIUM OF FORCES.

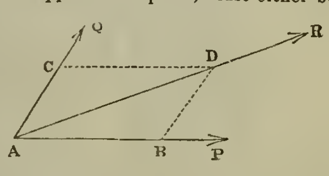
11. Variety of cases of equilibrium.—12. Parallelogram of forces.—13, 14. Equilibrium of three forces.—15. Superposition of forces in equilibrium.—16. Triangle of forces.—17, 18, 19. Equilibrium of many forces acting at one point: polygon of forces.—20. Resolution of oblique forces into perpendicular and horizontal forces.—21, 22, 23. Equilibrium of many forces in the same plane acting at different points—Moment of Force—Equality of moments.—24. Geometrical expression of this law.—25. Parallel forces.

11. The idea of equilibrium necessarily implies the idea of a plurality of forces, for one force by the definition produces motion. The simplest case of equilibrium of pressures is evidently that of two forces of equal magnitude, and acting in opposite directions on one point; in which the three elements of direction, magnitude, and point of application of forces are in their simplest relation. But as these elements may be variously combined in various systems of forces in equilibrium, there may be an infinite variety of particular cases. The conditions of equilibrium, however, are in all cases discoverable by the application of the fundamental law of the parallelogram of forces, now to be explained.

12. We may classify all systems of equilibrating forces into those in which the forces have a common point of application, and those in which they are applied to more than one point. And we shall consider first those systems of which the forces have their direction in one plane, noticing afterwards those of which the forces are not in one plane.

When two forces act together upon a point which are not in equilibrium, their statical effect must equal that of some third force acting singly at that point. The two former being compounded, are termed the *components*, in relation to the latter, which also is said to be the *resultant*, and which again may be *resolved* into the two.

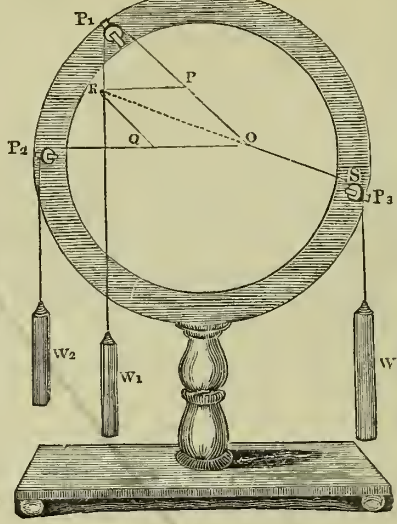
The direction of two forces applied to a point, must either be in one straight line, or contain an angle at that point. In the first case, their resultant will be the sum of the forces, if acting in the same direction, and their difference if acting oppositely. We shall consider these cases more at large when we come to treat of the laws of motion. For illustration of the second case, let two forces act on the point A in the directions A P, A Q, and with magnitudes expressed by A B, A C; their resultant, or the single effect of their joint action, is invariably found to be represented also both in direction and magnitude by the diagonal of a parallelogram of which A B, A C, are the sides. Draw C D, B D, parallel to A B, A C, respectively, and draw the diagonal A D; then A D, acting on the point A, is their resultant. This remarkable law, termed the law of the parallelogram of forces, may be shortly stated, thus :—*If two forces be expressed by the adjacent sides of a parallelogram, their resultant is expressed in direction and magnitude by the diagonal.* This law is the foundation of all statical inquiries; in fact the principle runs through every ramification of the science.



13. Now since the diagonal represents in magnitude and direction the effect of the joint action of the two side forces, it is clear that by applying a force to the point of application, equal and opposite to the resultant or diagonal effect, the three forces thus acting on it would be in equilibrium.

To prove this principle experimentally, take three weights, w^1, w^2, w^3, connected by cords of convenient length; and passing these over pulleys, P^1, P^2, P^3, fixed in a frame, let them hang till they settle in equilibrium. Then O, is the point at which the forces meet, being represented in direction by the cords; take O P, O Q, O S, along the cords, proportional to the weights w^1, w^2, w^3, respectively, and tracing the parallelogram O P R Q, on a surface behind, we shall find that the diagonal O R is

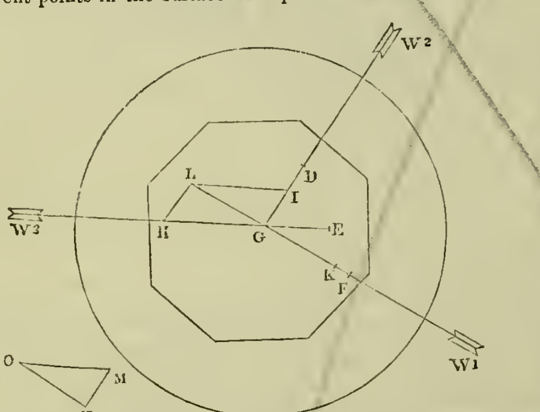
exactly equal and opposite to the line O S, showing that the components w^1, w^2, acting along their cords, on the point O, being expressed by the sides of a parallelogram, its diagonal will express their resultant, since it is equal and opposite to the force O S, exerted by the weight w^3, on the point O, and which keeps the other two in equilibrium. We may construct the parallelogram on either of the other two pairs,



w^1 and w^3, or w^2 and w^3, and we shall find that the remaining third force in each case will balance the resultant found.

Hence, in general, any one of three forces in equilibrium, and acting on a point, will be expressed by a line equal and opposite to the diagonal of the parallelogram formed by the other two.

14. Another mode of making the experiment on three equilibrating forces, is to suspend over pulleys set at the edge of a round table, the three weights, w^1, w^2, w^3, by their cords, to different points in the surface of a plane board, as F, D, E; this



board lying exactly horizontal upon three balls between it and the table, so as to be readily susceptible of motion, and also to counteract its gravity, which, if not neutralized, would interfere as a fourth force with the equilibrium of the three. When the whole has come to rest, we shall observe that the direction of the cords, produced if necessary, have one common point of intersection, G, which corresponds to the same point, in the previous experiment. If now we measure as many inches G K, O I, O H, along the cords as there are pounds in the weights they sustain respectively, and complete the parallelogram O I L H, the diagonal O L is equal and opposite to O K, the third force in the system; that is, it is in the same straight line with G K, and contains as many inches as are in it.

Now these experiments give results quite general, as regards the equilibrium of the forces acting in one plane; for, though we have experimented with *gravitating* force only, yet, as before noted (3), the abstract pressure is essentially of the same nature, whatever be its source.

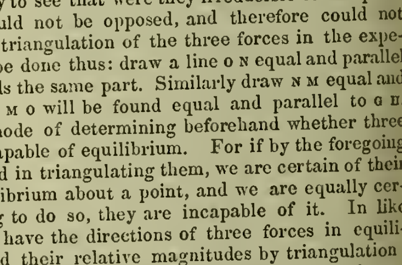
15. We have in this experiment touched on the doctrine of the *superposition of forces.* It is this: If a body be kept in equilibrium by any system of forces, and if to this be superadded another system of forces which would of themselves have kept it in equilibrium, then the resulting condition of the forces will still be equilibrium. For each system acts independently of the other, since what is called equilibrium of forces is the whole expenditure of their action among and against themselves—so that the two systems cannot interfere with each other, which is proved by experiment. In like manner, if from among a system of forces in equilibrium be abstracted a subordinate system of equilibrating forces, the remaining forces of the system must be in equilibrium. In the above experiment, we have the weight of the board itself, and the equal sum of the reactions of the balls as one system of equilibrating forces, and w^1, w^2, w^3, are the other equilibrating system.

16. Hitherto we have represented forces by the lines in which they act, expressing the three circumstances of direction, magnitude, and point of application. But it will often be preferable for purposes of reasoning to consider them represented by lines parallel to their direction and proportional to their magnitudes. Referring to the figure Art. 12, since C D is equal and parallel to A B, and D A is equal to and in the same line with the equilibrating force, the triangle A C D will represent by its sides A C, C D, D A, *taken in order*, the directions and magnitudes of the three forces. This may properly be called the *triangle of forces.* On the other hand, if the three sides of any triangle be taken to represent in magnitude and parallel direction, three forces acting on a point, they will be in equilibrium. For let three forces be represented in magnitude and direction by A C, C D, D A, acting on the point A, then the force represented by C D, is also represented by A B. Now A B and A C are equivalent to A D, that is, their effect is equal and opposite to that of D A, the remaining side of the triangle A C D, which will induce equilibrium. Therefore, if three forces acting on a point be represented in magnitude and direction by the three sides of a triangle taken in order, they will be in equilibrium.

The effects of forces are the same (10) at whatever points in their directions they be applied, so that the mutual intersection in one point of the directions of three forces is always necessary to their equilibrium, as was proved also by experiments (13) and (14), and it is easy to see that were they irreducible to one point of action, they would not be opposed, and therefore could not equilibrate. The triangulation of the three forces in the experiment (14), may be done thus: draw a line O N equal and parallel to G K, and towards the same part. Similarly draw N M equal and parallel to G I and M O will be found equal and parallel to G H. This suggests a mode of determining beforehand whether three given forces are capable of equilibrium. For if by the foregoing process we succeed in triangulating them, we are certain of their capability of equilibrium about a point, and we are equally certain that in failing to do so, they are incapable of it. In like manner, when we have the directions of three forces in equilibrium, we may find their relative magnitudes by triangulation; for the sides of the triangle will be proportional to the forces. Lastly, having their magnitudes, we may by constructing a triangle of which the sides are equal to the forces taken in order, ascertain their relative directions.

17. We have next to investigate the conditions of equilibrium of more than three forces acting on a point, and in one plane. Now, in estimating the whole statical effect of the forces, we may substitute for any two of them their resultant. In like manner, we may find a second resultant of this first one and a third force, and so on, combining them gradually into the whole effect of the system of forces. This is just a continued process of triangulation, and we shall proceed to its application in the following example :—

Let A P^1, A P^2, A P^3, A P^4, and A P^5 be forces acting on a point A. Now it matters not to the inquiry in what order we combine the forces; but we shall, for simplicity's sake, take them in their order of succession round the point A. The two forces A P^1, A P^2, being completed into a parallelogram by drawing P^2 B, P^1 B parallel to them, the dia-



a mass of moist clays, and observed in consequence, the formation of numerous fissures, more or less similar to slaty cleavage, in planes parallel to the bounding surface of the mass, and at right angles to the electric currents. The exact application of this experiment is not understood. Perhaps, however, conjoined with the admission, that the great movements of strata, by which slaty cleavage was determined, depended on the disturbed equilibrium of internal local weight, or rather must have developed electric currents;—this solitary experiment may be the commencement of a right mode of more extensive inquiry, embracing the many circumstances of chemical nature,—stratified arrangement, disturbed position, and proximity of aqueous rocks—which must all be included in a good theory of slaty cleavage." Indeed, there can be little doubt, that in all the phenomena which these rocks present, thermo-electrical action has performed a very important office, both in the re-arrangement of the molecules of matter, by which their cleavage has been determined, and their present structure produced, and we have no less an authority than Professor Sedgwick, for concluding, that they cannot be referred to retreat of parts, or contraction of dimensions, but to crystalline or polar forces, acting simultaneously in given directions on large masses, having a homogeneous (9) structure.

☞ (1) Lamelliferous, consisting of laminæ, or thin layers. (2) Zoophyta, coralline animals. (3) Brachiopoda, spiral armed molluscæ, or shell-fish. (4) Gasteropoda, snails, and other inhabitants of spiral univalved shells, as the whelk. (5) Cephalopoda, animals which, like the cuttle-fish, have their organs of prehension and progression situated round the head. (6) Conchifera, oysters, mussels, and other inhabitants of similarly constructed bivalves. (7) Anticlinal line, the line *from* which strata dip in opposite directions. (8) Synclinal line, the line *to* which strata dip from opposite directions. (9) Homogeneous, of the same nature, not mechanically compounded of different substances.

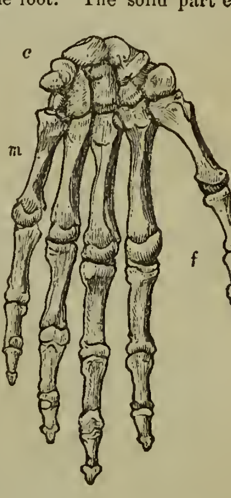
ANATOMY AND PHYSIOLOGY.

CHAPTER XI.

THE SKELETON.—*Concluded.*

The upper extremities have a strong general resemblance to the lower—the shoulder corresponding to the pelvis, the arm to the thigh, the fore-arm to the leg, and the hand to the foot; but the differences between them are also very striking. The lower limbs are formed for progression, and for supporting the weight of the rest of the body; the upper are formed for prehension—much less strong, but much more moveable. The shoulder is not fixed immovably to the trunk—the shoulder-blade glides on the back of the ribs, and is joined firmly to the outer end of the collar-bone; and the inner end of this is connected to a socket on the upper corner of the breast-bone, which permits great freedom of motion, but forms a centre round which the shoulder plays, so as to be raised or depressed, or carried forward or backward. The *collar-bone*, or *clavicle*, is slender, curved like a long italic *f*; and as all shocks produced by falls on any part of the upper extremity are transmitted through it—it is one of the bones most frequently broken. The *shoulder-blade* is triangular, with one angle directed downward, one upward, and one outward, and it covers the ribs from the second to the seventh. It is not, however, attached to the ribs, but is separated from them by a cushion of muscle upon which it glides. At its external angle there is a socket for the bone of the arm, so shallow that this bone is not laid into it, but merely against it, an arrangement which is one reason of the frequency of dislocations of the shoulder-joint. The bone of the *arm* is single, attached above to the shoulder-blade, and below to the bones of the fore-arm. It has a large round head, which is united by a ball and socket-joint with the shoulder, capable of motion in every direction; and by a hinge-joint with the fore-arm, capable of flexion and extension. It has two projections, externally, and internally, just above the elbow, which give the breadth to this part of the limb, and to which the muscles of the fore-arm are attached. The bones of the *fore-arm* are two, the *radius* and the *ulna*; the former being on the outer side, and the latter on the inner. The ulna is connected chiefly with the elbow-joint, and the radius chiefly with the wrist; so that when a fall is received on the hand, the force is transmitted through the radius much more than through the ulna; and, hence, the radius is broken much more frequently than any other bone in the body. The ulna is articulated very firmly to the arm-bone, and moves on it in flexion and extension; it can be bent up very close to it, and may even be extended very nearly into a straight line with it. The radius is very slightly connected with the arm-bone, and has a round head received into a cavity in the outside of the ulna, while at its lower end it has a cavity in its inner side, which rolls round the small lower end of the ulna. The effect of this arrangement is, that the ulna has always the same face directed forward, while the radius can roll round the ulna, so that its edge, or even its back, can be turned forward, carrying the hand along with it. This motion is commonly said to take place in the wrist, but, in reality, the wrist has nothing to do with it. It is called *pronation* and *supination;* the hand is said to be *prone* when its back, and *supine* when its palm is turned upward or forward. It is in this motion that the greatest difference is observed between the fore-arm and the leg: had any such motion been permitted in the leg, it would have produced instability. The two bones are connected in their whole length by a strong membrane, which gives origin to muscles, while it does not interfere with the rolling motion. The two extremities of the ulna, both upper and lower, are readily felt in the living limb, and afford a very ready standard of measurement from the elbow to the finger points, called the cubit, from the old Latin name of the bone, *cubitus.*

The Hand consists of twenty-seven bones, and is divided into three parts, analogous to those of the foot. The solid part entering into the wrist-joint, is properly called the wrist, or *carpus*, corresponding to the *tarsus* in the foot, but for obvious reasons greatly smaller, both in itself and in relation to the rest of the hand. Five long bones come next, making the palm, and fourteen very moveable pieces superadded, complete the fingers and thumb. In its construction, the whole hand differs from the foot, on account of its being intended, not for support, but to catch with, and all its parts are adapted to this end. Eight small bones are pretty firmly united to form the wrist, presenting a ball superiorly to enter the cavity in the lower end of the radius, fitted inferiorly to support the bones of the palm, arched behind to give it strength, and concave in front to permit the bloodvessels, veins, and sinews, to run to the fingers, without being subjected to undue pressure. In the palm we see the principal difference between the hand and the foot. In the latter, all the bones of the instep lie in one direction, immovable, and serving only to rest on. In the former, four of the bones of the palm are placed side by side, to form the hollow of the hand, and to support the fingers; while another, supporting the thumb, is very moveable, being capable of being brought opposite the others, so as to grasp firmly anything between it and them. The pieces of the fingers are considerably larger than those of the toes, and much more moveable, but are formed on a similar model. The fingers have each three pieces, the thumb only two. The last piece of each is expanded at the end, to support the nail on its back, and on its front the delicate pulp where the nerves ramify, and in which the nicest sense of touch resides.

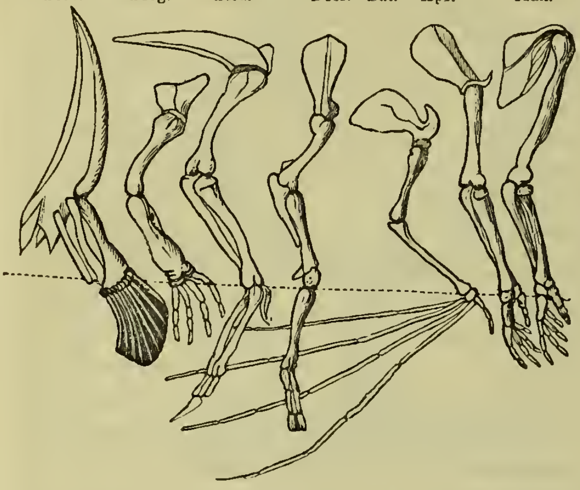


Front view of left Hand.

c, the eight bones of the carpus. *m*, the five bones of the metacarpus. *f*, the fourteen pieces of the fingers and thumb.

It is interesting to glance over the vertebrate division of the animal kingdom, and observe the modifications which an All-wise Creator has employed to fit the same bone or set of bones for different uses. The different genera whose fore-limbs are represented here, present very great differences; and to render these the more obvious to the reader, a line is drawn over the wrist-joints of each. In man, whose arm is to the left of the figure, and which we make our standard for comparison, the shoulder-blade

has the corner to which the arm is jointed, directed forward and outward, to let the motion of the arm be as free as possible,



while in the ape, it is directed more downward, because he walks on all his four hands. In the deer, and other quadrupeds, it is placed perpendicularly, because its only use now is to rest on the upper end of the arm-bone, transmitting to it the weight of the fore part of the body. In the bird and fish, it is elongated and narrow, because in them very little depends upon it. The collar-bone is not represented in any of the arms in the figure. We may remark, however, that while most perfect in man, it is wanting in most of the lower animals,—its use being to keep the shoulders separate, so that the arms may be crossed on the breast, to give a firmer point of resistance at the breast-bone, for anything to be pushed from, or pulled towards us, and to permit a free and sufficient extent of motion. Hence, it is found in those species only where the fore-limbs are much used for laying hold of objects, or for digging and scraping, as in the rat, the mole, the hedgehog, the squirrel, and monkey, up to man. In those who use them for scraping, striking, or tearing, though less freely, there is a loose bone like an imperfect clavicle, as in the cat, dog, bear, and lion. In those whose mode of swimming is by striking out, as the frog does, (for a frog is just like a man in his style of swimming), there are strong connexions between the shoulder and the breast-bone, serving for clavicles; and in birds, who strike out the same way in flying, there are strong clavicles fixed to the breast-bone so as not to allow of any motion, but to give very firm attachments to the wings. A clavicle would, however, have been worse than useless to the cow or the horse. When in running down a hill, we chance to fall on the hands or on the shoulder, one of the most common accidents is fracture of the collar-bone, because this bone is placed between the arm and the breast-bone, and consequently sustains a great part of the shock. But when a horse gallops down a hill, or takes a leap, no fracture is sustained, and yet the shock is greatly more violent. The reason of this is obvious from inspecting its skeleton, where we find that its fore-legs are not connected to the trunk by bones at all, but by immensely strong fleshy muscles passing from the ribs back to the shoulder-blades, between which the heavy body swings in safety.

The bone of the arm is in man longer than the fore-arm, which is not the case in any other instance in the figure. Its head is round, so as to permit free motion in every direction—while in most other animals its motion is confined—being limited in birds and most quadrupeds, to moving forward and backward, in the act of progression. In the fish it is very short in comparison to the rest of the member, which is, indeed, altogether very small in proportion to the rest of the body. The fore-arm in the ape has the power of rotation, as in man; and so it has in numerous animals who tear with their forepaws; and in the mole and ant-eater, who make their way by scraping and digging.

In the bird the radius and ulna lie parallel, and do not move upon one another; for there is no power of grasping enjoyed by it. In the bat, for the same reason, the radius alone reaches to the hand, the ulna ending in a delicate point, about half-way down. In quadrupeds, like the deer, which use the fore-leg only to rest on, the two bones admit of no motion; and in some they appear almost fused into one.

The bones of the hand vary very much, according to their offices in the different orders of vertebrate animals. The small round bones composing the wrist, are found with more or less modification in all. But the hand is formed perfect in man only. The ape, who comes nearest to him, has the thumb very short and weak, being scarcely longer than the metacarpal bone of the forefinger. In the bat, the pieces of the fingers are seen to be very long and delicate, for the membrane to be stretched on, which enables them to serve for wings. In the fish they are numerous, and placed close together, to form a fin. In the frog, for the same reason, they are webbed. In the bird they are few and short, while the metacarpal bones are long, to give support to the large feathers of the wing. In the quadrupeds with claws they are all placed side by side; and those who have hoofs, as the deer, cow, and horse, have but one or two, according as the hoof is single or divided, placed nearly perpendicular, and walk, as it were, on the points of their toes and fingers, the part of the hoof which rests on the ground corresponding to the edge of the nail.

In concluding the account of tho skeleton, and of this particular part of it, I cannot recommend a more interesting work than the Bridgewater Treatise, by the late Sir Charles Bell, on "The Hand, its Mechanism and vital Endowments, as evincing Design;" in which the form, connexions, and relation to the rest of the body, and to the uses it is to subserve, are illustrated in a most beautiful manner, by comparison with the skeletons, limbs and habits of other vertebrated animals, both those at present existing, and those which have existed in former conditions of our globe, to whose state they were adapted. And I shall quote from him the following sentence, which he, in turn, quotes from Ray, an old writer:—"Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks: man hath none of all these, but is weak and feeble, and is sent unarmed into the world.—Why? A hand, with reason to use it, supplies the use of all these."

The size of the skeleton varies very much, ranging from thirty-five inches to eight feet. The gigantic skeleton of the Irishman, O'Brien, preserved in the museum of the College of Surgeons in London, measures eight feet two inches. What is called the middle size in man, is about five feet four inches; in woman, about five feet. When the bones have been cleaned and dried, the weight of an ordinary male skeleton ranges from ten to thirteen pounds; of a female one, from eight to nine.

In early life, when their animal material preponderates in quantity (see p. 269), the bones are full of bloodvessels, and comparatively soft, flexible, and springy; and though liable to many serious diseases, they are very apt to escape the effects of injury. It is not common to meet with fractures in young children; and sometimes their bones, bending rather than breaking, suffer that partial fracture which has been compared to a "branch of a tree that yields to an attempt to break it while it retains its sap." The power of repairing injury is proportioned to the full supply of blood at this period; fractures are speedily re-united, and their effects so regulated by the subsequent growth of tho bone, that permanent deformity is a very unfrequent occurrence.

The osseous system cannot be considered as being arrived at maturity until a period long subsequent to the age of puberty; most commonly somewhere between the twenty-second and thirtieth years. The bony tissue is now so constituted as best to answer its purposes in the bodily frame; it is now least liablo to disease; and if fractures and other injuries be more frequent, it is only because individuals are now more exposed to them. The effects of such injuries are, in general, tolerably repaired; but if deformity be the result, it is permanent; because the bone has now ceased to grow. As life advances, the osseous system undergoes many obvious alterations. The shape of some bones is altered, and the texture of all is somewhat changed, with an increase in the earthy material over the animal constituent—so that fracture is more apt to happen to the bones of the aged, from even a less serious fall or twist.

When fracture has taken place, if the bone be kept at rest, the *fibrin* of the blood is poured out around it, from the small bloodvessels which have been torn. This fibrin attaches itself to the periosteum round the fracture, enclosing it as in a bag.

On the inside of this bag, and on the outside of the bones, new bony matter is deposited from the blood, and, by and by, the fracture is enveloped in a ferule of new bone—which bony matter is also formed between the broken ends, cementing them directly together. This sort of ferule is felt as a lump on the bone, for a long while, but as the direct connexion of the broken ends becomes stronger, it disappears, being now less needed. The bones of the upper extremity are generally united in three weeks, those of the leg in a month, and the thigh-bone in about six weeks; but even at these periods they are not so strong as to bear rough usage.

When a bone is broken, it must be obvious that the muscles will no longer produce the natural action which the bone served to direct, but will draw the piece that is broken off into some place where it ought not to be. When the thigh-bone is broken, for example, the strong muscles which pass along it from the pelvis to the leg, pull up the lower fragment, so that the limb becomes shortened. It is also apt to be distorted, by the loose piece being pushed by violence, or pulled by the muscles, to one side or the other. In treating fractures, we begin, therefore, first to reduce them, or bring the broken ends into their proper places, and then we have to maintain them in apposition, by the application of splints and bandages, which will keep them immovable till union shall have been obtained.

When there is no wound accompanying it, a fracture is styled *simple;* when a wound passes down to it, so that there is a communication between the broken ends of the bone and the external air, it is called *compound*, and becomes a very dangerous matter. A compound fracture takes many weeks, or even months, to mend; and frequently it will not mend at all, but causes a profuse suppuration, so that the limb must be amputated, to give the patient even a chance of surviving.

Sometimes we meet with defective states of the nourishment of bone—so that it becomes very brittle or very soft. In the former case, fractures will happen to almost every long bone in the body; in the other, they bend under the weight of the limbs, causing great deformity; and sometimes, after this deformity has taken place, they become unnaturally hard, producing, of course, deplorable and incurable decrepitude.

Ulceration and mortification take place in bones, as well as in the soft parts; and a very curious affection occurs, called *necrosis*, when a bone dies, and a new one grows round about it, to supply its place, after which the old one is thrown off, or, more commonly, requires to be removed by the surgeon. Scrofulous diseases of the bones are very common, and give much work for the surgeon: other constitutional affections attack them also. Several forms of cancer, and other incurable changes of structure analogous to it, also attack bones; and death can be avoided only by the removal of the whole bone affected.

ON THE MANUFACTURE OF CAST-IRON.

CHAPTER III.

ON THE USE AND THEORY OF THE HOT BLAST.

In the former chapters we endeavoured to show that the irregularities of the blast-furnace arose partly from atmospheric changes in the volume of the air, and partly from the construction of the furnace itself, by which a portion of the metal, in falling through the blast, becomes oxidized; and as a portion of the blast comes into direct contact with the incombustible matters of the charge, and the intensely heated sides of the hearth, it may become so much rarefied as to be rendered unfit for supporting the combustion of the coke, or even for decomposing the carbonic oxide. The vitreous matters, likewise, being chilled and solidified by the rush of cold air, prevent the free application of the blast upon the fuel. These obstructions, also, cause the focus of combustion to shift from place to place in the furnace, and by this means a portion of the metal becomes prematurely melted down, while only in the state of steel or hard cast-iron; while in the part of the furnace where the blast is obstructed, scaffolds are produced. These again by giving way form new openings for the blast; and, at times, they even choke up the tuyères altogether, from the quantity of fluid metal brought down along with them, to the great annoyance of the furnace-keeper. All these evils might be lessened, if not entirely avoided, by an alteration of the furnace; for, by keeping the ore longer in a state of cementation, and by applying the blast to the fuel in a diffused or gentle stream, as is done in the air or pit furnace, the combustion would be more perfect, and the heat more uniform.

We shall now advert to the use of rarefied air, or the hot blast, as it is called. In 1804, hot air was tried at the Bradley Iron Works, in the smelting of iron, but was given up in consequence of the puddlers complaining that, since the hot air was used, the iron had become so rich and gray that it would not answer for puddling, and they could make nothing of it. After using it for about three months it was abandoned, as the iron produced by it was unsuitable for their purpose—it being forge pigs, and not foundery iron they wanted. In 1817, Mr Stirling, an ingenious gentleman, belonging to Ayrshire, took a patent for a means of economizing fuel by retaining the waste heat that is constantly escaping from furnaces, by means of the fresh air with which the furnace was afterward to be supplied; conceiving that, by this means, more heat might be obtained from the same consumpt of fuel, by the caloric accumulating in the furnace, which he considered would at least be equivalent to the difference of temperature imparted to the blast, above the temperature of the atmosphere. However, from the necessary expense of the erections for retaining and transmitting the heat to the fresh air, and the small amount of saving likely to be derived from it, this patent never was brought into use. Akin to this is another patent of a still more recent date, to which the patentees have given the name of *hot-blast*, and which has now been adopted by most of our Scottish smelters. From the vague manner in which this specification is drawn out, it is perfectly impossible, without the aid of a letter of the inventors to Dr Cleland, to discover in what they consider the invention to consist. However, this letter and Professor Clark's paper give us a clue to the whole, especially as these are also confirmed by the belief of the smelters who have adopted it. This invention, therefore, may be considered—1st, as a means of increasing the velocity of the blast without a corresponding increase of power from the blowing engine; and this, the patentees seem to imagine, can be effected by expanding the air by heat after it has left the blowing cylinder; 2nd, that by this heating of the air before applying it to the support of combustion, they seem to think that the combination with the fuel must be more rapid; and, that by this means, they can produce a much more intense heat in the hearth of the furnace than when cold air was used. "Because," say they, "from the enormous quantity of air required for the support of combustion in a blast furnace, it must absorb and carry off a great proportion of the heat; and, therefore, from the heat in the air, and the increased energy of the combustion less fuel should melt the ore with the hot than with the cold blast." And, in proof of the efficacy of their invention we are told, that when they heated the air to 300°—for which they required 8 cwt. of coal for the heating process—they obtained such an increase of temperature in the furnace as would have required 58 cwt. of coal, or 7¼ times the quantity to have been consumed in the furnace itself with the cold blast. And, again, when they raised the blast to 600°, 8 cwt. of coal, consumed in the heating furnace, produced a saving of 116 cwt. in the large furnace. However, as the patentees seem to have forgotten that air expands in all directions, their first idea of increasing the velocity of the blast, without increasing the resistance against the piston, appears to me to be altogether erroneous. And, again, that 8 cwt. of coal, when consumed in a separate furnace, should be capable of generating so much heat in the large furnace—and this too in a detached building situated at some distance—and, at the same time, that such an increase of heat could have been produced by blowing the furnace with the same pressure of blast, and from the same orifices, or nozzles, as were used with the cold blast, but, now, with air rarefied to half an atmosphere; or, in other words, by discharging into the furnace a blast only equal to half the quantity that was used in the state of cold air; but now expanded to the same volume as the cold blast—the very means by which combustion in the large furnace ought to have been rendered still more gentle and diffuse—is an idea so un-

philosophical, as at once to create a doubt that this supposed increase of heat in the furnace does not take place; and that they must be in error here also. Again, from Mr Dunlop's table in the appendix to Professor Clark's paper, it is there stated that, with the cold blast, the weekly consumpt of fuel was about 3 tons 12 cwt. of coke, while, when the air was heated to 300°, about 2 tons 7 cwt. sufficed; and with four furnaces, and the air heated to 600°, only 2 tons 5 cwt. of green coal, in place of coke, were used to the ton of iron. In page 6, we are likewise informed that, during the successive periods specified, the same blowing apparatus was in use, and the furnaces at Clyde Iron Works, which were at first three, had been increased to four, and the blast machinery being still the same, &c. And, in the last page of the appendix, the blowing engine has a steam-cylinder of 40 inches diameter, and a blowing cylinder of 8 feet deep, and 80 inches diameter, and goes 18 strokes a minute. The whole power of the engine was exerted in blowing three furnaces, as well as in blowing four; and, in both cases, there were two tuyères of 3 inches diameter to each furnace. The pressure of the blast was $2\frac{1}{2}$ lbs. on the square inch. The engine then went less than 18 strokes a minute, in consequence of the too great resistance of the materials contained in the three furnaces to the blast in its passage upward. These statements being quite at variance with the known laws of the elasticity of air, to conceive that, with a uniform pressure of $2\frac{1}{2}$ lbs. to the square inch, the same quantity of air should be discharged through the same orifices when expanded to more than double its former volume, at once awakened my suspicions that they must be deceiving themselves with this also; and, at the same time, it seemed to afford me a key to the whole of the mysteries of this saving of fuel by the use of the hot blast. However, before saying anything more on the subject, I resolved to see some of the smelters, and hear their opinion of this singular and obvious overlook in the appendix. On calling their attention to it, I was not a little surprised to find that this was their opinion also, and that their blow-pipes were still of the same size as when they were using the cold blast—that the pressure they used was still the same—that their engines were wrought at the same speed as formerly—and that they were not letting any of the blast escape—neither was there any extra leakage in the heating apparatus, at their works, so far as they were aware.* Indeed, I found that all with whom I spoke believed it to be the case, as stated in Professor Clark's paper. However, as I knew this to be impossible, I again pressed the question on one of the most scientific of the gentlemen, and he admitted that he had taken the patentees' word for it: he had made the same objection to them when it was first spoken of, but was assured of its being a curious fact, that the dilating of air by heat made no difference whatever in this respect. As I considered the assertions of a sanguine or interested patentee no authority, he then, by way of convincing me, observed that, perhaps, air at a high temperature might be like a sponge full of water, which was much easier squeezed to half the size, than to squeeze it dry; and, therefore, he considered it would take little or no more power to force air through the same aperture at 600°, than when cooled down to 32°. Whether this also was the general belief of the smelters I did not stop to inquire. At any rate I found they all approved of the use of hot air, although they admitted that they could produce no more iron with it, than the English smelters did with their cold blast, from the Scotch coals not being so durable; neither could they produce quite the same results as were stated of the Clyde Iron Works. Still, they could now use green coal, which they said they could not do with cold air, because they found that when any of their heaters gave way, and they were obliged, for a time, to have recourse again to the cold air with the green coal, their iron became hard, and inferior in quality, by the furnace becoming lower in temperature, from the want of the extra heat afforded by the hot blast. And, in proof of this opinion, they asserted that, it is want of heat alone that causes the furnace to produce bad iron; for in damp weather, say they, combustion cannot go on with the same energy, and therefore the furnace must become cooler, and the iron hard. And they asserted also, that the hot air must, to a certainty, increase the heat of the furnace, and therefore they concluded that the iron must be good from the use of the hot blast. Another reason they gave in favour of it is, that their furnaces are more easily managed, not being so liable to choke and form tuyères across the hearth—or brigg up as they call it—and they complained of the heating apparatus being a great additional expense. And further, they thought that something is gained from less power being necessary to blow the furnace with the hot air, because they conceived that the increasing expansion of the air, as it passes along the pipes, makes it rush into the furnace from the blow-pipes with a much greater velocity than the power of the engine could impel it with.† However, since the smelters seem quite satisfied with these explanations of the effects of hot air, although in direct opposition to the known laws of temperature and elasticity of the air—we shall leave them to their own opinions and return to their furnaces—and although rather unwieldy eudiometers to experiment with, still, we may discover from them how far this heating of the air will affect their rate of combustion, and also how much air has been used from the quantity of fuel consumed. For it must be evident that if this heating of the air increases the heat of the furnace so wonderfully, it must likewise accelerate the rate of combustion of the fuel also; and, therefore, if they are right, a greater quantity of fuel must be consumed in a given time by the hot than by the cold blast, and since the combination of the oxygen in the blast, with the coke, is the sole cause of its disappearing, or sinking down from the tunnel head, to replace that which has been consumed; therefore, this consumpt of the coke will afford us a means of determining the quantity of air that has been blown into the furnace in any given time also. Now, from the data furnished to Professor Clark by the patentees, from the work belonging to one of themselves, and therefore under their own immediate inspection, we find that the successive weekly consumpt of fuel put into the three furnaces at Clyde Iron Works, was as follows (the blowing machinery being still the same):—

	Tons.
With the cold blast,............	403
With blast heated to 300°, (expanded about ½ more in bulk),............	360
With the blast heated to 600°, (or expanded to fully twice the bulk),............	188

this last being about the quantity of coke contained in the 416 tons of green coal, which is the proportion for three of the furnaces. Now, if we allow a little for the loss of heat by radiation and the imperfection of their first heating apparatus—which they acknowledge to have been imperfect—the consumpt of fuel

* In these conversations with the smelters, I observed that, since this was the case, they must only be using one-half of their former blast, and that it should be called half-blast and not hot-blast, as it was the want of air that saved the fuel—but this they would not admit. However, in the autumn of 1837, (after I had read this paper,) I again met two of them, and the conversation turned upon it. They now admitted that I was right after all as to the hot air being only a half-blast; because, with the same cylinder, they were now blowing more furnaces with the hot, than they formerly could do with the cold air. And they laughed heartily at a singular explanation of this mystery, afforded by the answer of an engine-keeper of a neighbouring work, whose manager was a great advocate for the hot-blast; when asked by one o their engine-keepers how he managed to keep his engine so regular,—he replied, Oh, I ju t let off the spare blast *quietly*; 'tis by far the best way of regulating the blowing-engine when she is overburthened at any time, just to let off the spare blast till she comes to her proper speed. I shall just mention another proof drawn from Clyde Iron-Works itself. Having visited this work in 1840, to see their new blowing-engine, along with a young friend who had been engaged in its erection; as I had previously explained to him my views of hot-blast, to show him I was right, I put the following questions to the engine-keeper. What is the use of heating the air? Oh, 'tis to make the furnace hotter; so much cold air in the cold blast cooled the furnace very much. Did you ever attend a cold-blast engine? Yes, for four or five years. Does it make any difference upon the engine to blow the cold or the hot blast furnaces? Oh, yes, it makes a great difference; the hot is much easier blown than the cold; the same engine that could only blow three furnaces with the cold, can now blow five with the hot. And with the same blowing cylinder? Yes, with the same blowing cylinder, she can now blow five, while she could only blow three with cold-blast. Then could you tell by the working of the engine, if the fire-men, at the furnaces for heating the pipes, were neglecting their fires, or letting their pipes become cool? Yes, I can tell when they neglect any of their fires; but I cannot tell which it is till I go and see. How do you know by the engine? Because she goes quicker; sometimes she will make two strokes a minute quicker.

† Having had occasion to call upon an engineer, I found him engaged with a smelter, who was relating to him the following as a very curious experiment he had just made:—We were getting a new set of heaters for one of our furnaces, when I caused a small hole to be drilled through each pipe, just at the top of the bend, so that I might test the pressure in each. After they were in full operation, I tried each pipe with a pressure guage; and strange to say, I found the pressure the same over the whole of them—it was quite the same in each pipe. My friend remarked rather drily, I think you might have expected that. Well, said he, I can assure you it is the general belief in the trade, that the pressure is different in each pipe, and that it continues to increase as the air becomes heated in its passage through them, until it gets off at the nozzles; but this is not the case after all, although it was upon this principle the patent was taken out. And it was just because I had some doubts about it that I resolved to try it, and now I find it is not so.

MR ROBERTON'S TABLE OF PITCHES. &c.

Pitch in Inches.	Thickness of Teeth in Inches.	Breadth of Teeth in Inches.	H. P. at 4 feet in 1″.	H. P. at 3 feet in 1″.	H. P. at [illegible] feet in 1″.	H. P. at 8 feet in 1″.
3·99	1·9	7·6	27·43	20·57	41·14	54·85
3·78	1·8	7·2	23·32	17·49	34·98	46·64
3·57	1·7	6·8	19·65	14·73	29·46	39·28
3·36	1·6	6·4	16·38	12·28	24·56	32·74
3·15	1·5	6·	13·5	10·12	20·24	26·98
2·94	1·4	5·6	10·97	8·22	16·44	21·92
2·73	1·3	5·2	8·78	6·58	13·16	17·54
2·52	1·2	4·8	6·91	5·18	10·36	13·81
2·31	1·1	4·4	5·32	3·99	7·98	10·64
2·1	1·0	4·	4·0	3·0	6·0	8·0
1·89	·9	3·6	2·91	2·18	4·36	5·81
1·68	·8	3·2	2·04	1·53	3·06	3·08
1·47	·7	2·8	1·37	1·027	2·04	2·72
1·26	·6	2·4	·86	·64	1·38	1·84
1·05	·5	2·	·5	·375	·75	1·

MR CARMICHAEL'S TABLE OF PITCHES, &c.

Pitch in inches.	Thickness of teeth in inches.	Breadth of teeth in inches.	Length of teeth in inches.	H. P. at 2·27 feet in 1″.	H. P. at 3 feet in 1″.	H. P. at 6 feet in 1″.	H. P. at 11 feet in 1″.
3·99	1·9	7·6	2·28	12·03	15·90	31·80	58·30
3·78	1·8	7·2	2·16	10·80	14·27	28·54	52·32
3·57	1·7	6·8	2·04	9·63	12·72	25·54	46·68
3·36	1·6	6·4	1·92	8·53	11·27	22·54	41·32
3·15	1·5	6·0	1·80	7·50	9·91	19·82	36·33
2·94	1·4	5·6	1·68	6·53	8·63	17·26	31·64
2·73	1·3	5·2	1·56	5·63	7·44	14·88	27·28
2·52	1·2	4·8	1·44	4·80	6·34	12·68	23·24
2·31	1·1	4·4	1·32	4·03	5·32	10·64	19·54
2·10	1·0	4·0	1·20	3·33	4·40	8·81	16·15
1·89	0·9	3·6	1·08	2·70	3·57	7·14	13·09
1·68	0·8	3·2	0·96	2·13	2·81	5·62	10·33
1·47	0·7	2·8	0·84	1·63	2·15	4·30	7·88
1·26	0·6	2·4	0·72	1·20	1·59	3·18	5·83
1·05	0·5	2·0	0·60	0·83	1·10	2·20	4·03

ANATOMY AND PHYSIOLOGY.

CHAPTER XII.

THE JOINTS.

The bones composing the skeleton are articulated, or joined, to one another, in three different ways. 1st, They are found dove-tailed into one another, with the intervention of a very thin layer of cartilage, and are quite immovable. 2d, They are connected by means of one or more layers of cartilage between them, and ligaments or fibrous bands on their outsides, tying them together, and admitting of more or less motion. 3d, They are united by means of cartilages, ligaments, and synovial membranes, which united apparatus form the most perfect joints, such as are found between the bones of the extremities.

The unions of the bones of the cranium are called *sutures*, from the Latin word signifying to sew, because they seem as if stitched together; the fibres of the one bone forming prolongations which pass into the notches or spaces left by the similar prolongations of the other, as is seen in the figure of the skull already given at p. 296, *ante*. Between these runs a thin layer of cartilage. These sutures run in determinate lines over the head, as seen in the drawing of the cranium just referred to; but, in an article of this kind, for popular reading, it would be out of place to give a more detailed description of them.

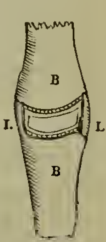
The bones of the spine are united by thick layers of a peculiar cartilage, mixed with ligaments, placed between them, admitting of but little motion between any pair of bones, but allowing considerable curvatures to take place in the whole length of the spine. The reason of this arrangement obviously is, that the spinal marrow which is contained in the canal formed by the contiguous rings of the twenty-four vertebræ, may not be subjected to any injurious pressure or twisting at any one point; and the proof of this remark again is, that when a man has his spine fractured or dislocated, the spinal marrow is either torn through, or pressed upon so as to be unfit for its office, or an inflammation is excited in it, which results in its destruction, so that incurable palsy, and a piecemeal death, are sooner or later the results. Strong ligaments also pass down the spine in front and behind, binding its different pieces together. A very beautiful adaptation of the joints of the spine to the habits of its possessor may be observed in a cod, salmon, or other large fish, where the opposed surfaces of the vertebræ will be found hollowed so as to form two cups, between which an almost jelly-like cartilage serves as a ball, thus completing a double ball-and-socket-joint. In the human spine, because its motions are not required to be so extensive, the resemblance to a ball-and-socket-joint is but remote, yet still the principle on which it is formed is quite the same.

Ligaments, it should be stated, are composed of numerous straight fibres collected together, and arranged into short bands of various breadth, parallel or radiating, and interwoven with others which cross them, so that they cannot, even on the dissecting-table, be split up into threads. Sometimes the ligament is so formed as to surround the articular ends of two bones which move upon one another, and here it is called a *capsule*, or *capsular ligament*. Ligaments are not extensible nor elastic; hence, when any attempt is made to stretch them too far, great pain is the result, and inflammation follows, and they are said to be *sprained*,—if the force applied be greater still, they may even be entirely ruptured.

The different parts of the pelvis are united by means of cartilage and ligaments, each bone having its articular surface covered with cartilage; and these are laid together, with or without the intervention of a third layer, and are bound firmly by ligaments passing over them. Such are the joints between the two haunch-bones, and between them and the rump-bone.

The joints of the extremities, it has already been remarked, are of a more complicated nature. The ends of the bones entering into the joints, having their forms adapted to one another, are covered with cartilage, then they are tied together by ligaments; and, in addition, a membrane called *synovial*, is spread over the ends of the bones and lines the ligaments, forming a shut bag, whose inner surfaces are everywhere in contact, and to obviate friction are moistened with a bland mucilaginous fluid. called *synovia*. The synovial membrane has a smooth velvety surface, like the membrane which lines the mouth and nose. The fluid which serves the purpose of oil to the joints, does not, in reality, contain any oil, yet it has very much the feeling of oil when rubbed between the fingers. When it increases too much in quantity it produces dropsy of the joints.

The figure in the margin is a plan of a finger joint, one of the simplest of the perfect joints. B B are the two bones; L L, the two side ligaments, which may be felt at the sides of the finger, tying together those parts of the two bones between which there is the least motion. The cartilages are seen marked by cross lines, covering the ends of the bones, and inside of these, the synovial membrane is seen lining both them and the ligaments. A space is represented within the joint, merely for the sake of making its component parts plainer; but, in reality, there is no space or cavity within a joint, all the surfaces being in close contact.



The structure of articular cartilage has been already described in p. 268; it is only necessary here to remark, that it seems to prevent any of that jarring which might be expected to result, were the hard surfaces of bones to be brought with violence immediately into contact.

The motions permitted in joints may be referred to four heads; viz., gliding, flexion and extension, circumduction, and rotation. 1st, *Gliding* is the simple movement of one articular surface upon another, and exists to a greater or less extent in all the joints. In the least moveable joints, as those of the solid parts of the hands and feet this is the only motion which is permitted.

2d, *Angular movement* is seen most simply in the joints of the fingers, where no other motion is permitted but that of *flexion* and *extension*. At the joint between the metacarpal bone and first bone of the finger, *adduction* and *abduction* are also permitted; that is, approaching to or removing from its next neighbour. 3d, *Circumduction* consists in the performance of these four motions consecutively, flexion, abduction, extension, adduction, as is seen in making the point of the fore-finger describe a circle, having the metacarpal joint for its centre. 4th, *Rotation* is the rolling of a bone upon its own axis, as is seen in the hip and shoulder-joints, the upper end of the radius in pronation and supination of the hand, and the articulation between the first and second vertebræ of the neck, when the head is turned shortly round from side to side.

The head is set upon the first vertebra of the neck, through the medium of a couple of joints, admitting of only flexion and extension. When a quick short nod of the head is given, the motion takes place here. The first vertebra of the neck is a circle moving round a pin projecting from the second vertebra—thence called the *axis*—carrying the head round with it, in the quick short movement of looking sidewise. The only complete dislocation that takes place in the spine is at this joint, in consequence of the destruction of a ligament which keeps the bones in their places. When this happens the weight of the head makes it fall forward, carrying the first vertebra with it, and the spinal marrow is so nipt between its ring and the projecting pin of the second, that the sufferer dies as surely and as instantaneously as if his neck were severed by the axe of the executioner. In a man, who is hanged, too, this is generally the cause of death; not, indeed, in one who deliberately suspends himself in his own handkerchief; but the criminal who is launched from the drop, with a fall of several feet, and dies instantaneously, has his neck dislocated, while he who struggles perishes from suffocation.

The articulation of the lower jaw, with the temporal bone, is almost completely a hinge-joint. The upper end, or *condyle*, of the jaw-bone is covered with cartilage, and so is the socket, and the two bones are tied together by side ligaments. Besides, there is a moveable cartilage in the joint which accompanies the condyle of the jaw in its motion. Notwithstanding all these appliances, the jaw is sometimes dislocated, slipping forward off the eminence upon which it gets when the mouth is opened. When this accident takes place, which generally happens from a violent yawn, the patient is left with his mouth wide open, and has not the power of closing it, presenting a very ludicrous figure to his companions, though his situation is to himself sufficiently uncomfortable. After this dislocation has happened it is exceedingly liable to be reproduced, in consequence of the torn ligaments never properly uniting. The story has been often enough told of the surgeon who was dissatisfied with the scurvy fee offered him for reducing a gentleman's jaw, sitting down and exciting a yawn by telling a tiresome story, and opening and shutting his snuff-box lid, till the patient's jaw opened and slipped out again, and then refusing to replace it until a handsome *honorarium* was laid upon the table.

Strong bands of fibres tie the collar-bone to a slight hollow in the upper corner of the breast-bone; the motion is very free, and to render it the more so, a moveable cartilage is interposed between them. This joint is very rarely indeed injured. The collar-bone and shoulder-blade are very firmly bound together so as to move as one piece, and yet a slight yielding is permitted, otherwise, as they stand at right angles to one another, fracture or dislocation, about this joint, would much more frequently occur.

The shoulder-joint is of all others the most frequently dislocated. This results partly from its form, and partly from its being more exposed to violence—since every fall, whether upon the shoulder, arm, or hand, has a tendency to displace it. The cavity on the shoulder-blade is so small and shallow, that the round head of the arm-bone is laid not in it, but on it; its barrel-shaped capsular ligament is strong, but loose, so that the bone depends for being retained in its place, upon the muscles which surround it; and if these be overcome, or taken by surprise, particularly when the arm is raised above the head, the head of the bone is dislocated down into the arm-pit. It is, in general, replaced without much difficulty, but is exceedingly liable to be thrown out again. The author recollects one man, who fell into fits occasionally, whose shoulder-joint he saw dislocated, and assisted to reduce, three times, on three successive days. The shoulder-joint admits all the varieties of motion described in a preceding paragraph.

The elbow-joint is more complex than the shoulder. It is double in its motions, admitting of the flexion and extension of the fore-arm on the arm, and the rolling of the head of the radius. For the first motion it has two strong lateral ligaments, which may be felt at the two sides, rendering it a hinge-joint; and, for the second, the neck of the radius is confined to the side of the ulna by a collar in which it rolls. A synovial membrane covers the ends of the bones, and lines the different ligaments. It may be dislocated in many directions. Both bones of the fore-arm are, most commonly, thrown backward, as in consequence of a fall on the hand—then the arm is nearly straight, and cannot be bent. Sometimes the fore-arm is thrown sideways, either outward or inward, and sometimes the radius is dislocated alone—backwards, forwards, or outwards. From its complexity it is also exceedingly subject to disease.

The wrist is a hinge-joint, moving backwards and forwards, and also allowing the hand to be carried a little edgewise, outwards or inwards. The lower end of the radius forms a socket in which the uppermost two bones of the wrist move, united so as to form an oblong ball. Two lateral ligaments confine the hand to the lower ends of the radius and ulna, and the whole joint is lined by a synovial membrane. This joint is almost never dislocated; but it is liable to sprains, and to disease, producing occasionally the loss of the hand.

Closely connected with the wrist-joint, although not actually forming a part of it, is the joint between the lower ends of the radius and ulna. Here there is a socket in the edge of the radius, which is made to revolve round the small lower end of the ulna which remains fixed, while the hand is thrown, alternately with its palm and its back, forwards.

The bones of the hand are not subject to dislocations, except at the joint between the first and second pieces of the thumb—a seemingly trifling affair; but one which is extremely difficult to set to rights—so much so, that many of those who are the subjects of this accident, continue to go with the point of the thumb bent back all the rest of their days.

The hip-joint consists of a deep socket in the haunch-bone, into which the round head of the thigh-bone is set. A capsular ligament, of great strength, of a barrel-shape, attached round the edge of the socket and to the neck of the bone, fixes it in its place. The opposed surfaces of the bones are covered with cartilage and are tied together by an internal ligament. A new explanation of the use of this ligament has been given within the last few years, from which it would seem that, as its attachment to the thigh-bone is on a higher level than its connexion to the bottom of the socket, the superincumbent weight rather swings from, than rests on, the head of the thigh-bone. The whole is lined with a synovial membrane. This joint, notwithstanding its strength, is subject to dislocation, principally on account of the long lever which the thigh-bone affords to any force acting upon it, so as to tear the head from its socket.

The knee is the most complicated joint in the whole body. The ends of the thigh-bone and *tibia* are each covered with cartilage, and in contact, but neither of them is hollowed—so that the joint does not depend for strength on its form, but on the number and strength of its ligaments. Two of these are placed externally and internally—as in all hinge-joints—and seven others are arranged, in different positions, within and without it. The knee-pan is placed in front of it, and the whole is lined with a synovial membrane, which is the largest in the body—hence the fever and extreme constitutional disturbance that arise when this joint becomes inflamed. It lies very superficial, being covered only by the skin in the greatest part of its extent; and hence it is very easily wounded by a cut or prick from any sharp instrument. It is never dislocated, except by such a force as destroys it altogether, and necessitates the immediate removal of the limb by amputation.

The ankle is a hinge-joint, having one lateral ligament on its inner, and three on its outer side. The upper surface of the *astragalus*, as has been already said (p. 297, *ante*), is like the half of a broad pulley; it plays against the lower hollow end of the *tibia*, and is received between the two ankles, formed by it and the *fibula*. This part of the *astragalus* is narrower behind than in front, so that when the foot is at right angles to the leg, as we stand on it, the broad part is between the ankles, and it is firmly fixed · but when the foot is extended, pointed downward, the

narrow part is brought between them, so as to admit of the toes being directed to either side. The ankle-joint may be dislocated forwards, or to either side. This never happens without one of the ankles being broken off, the ligaments being so strong that the bone will break rather than they should give way. The dislocation of the ankle can scarcely take place without a wound coexisting. And here is a suitable opportunity for explaining what is meant by a simple, and what by a compound dislocation.

A *simple dislocation* is one where the bones are displaced, but the joint is not laid open; a *compound* one need not be more serious in so far as the bones are concerned, but is accompanied with a wound leading into the joint, which, consequently, inflames and suppurates, and brings the sufferer into great danger of losing his limb, if not his life. In the same way, a *simple fracture* is when a bone is broken without a wound; a *compound* one is where there is a wound communicating with the broken surfaces.

The joints across the foot are numerous, and not easily described in a treatise of this kind. There is one joint across the middle of the *tarsus*, or solid part of the foot, which, in some persons, admits of a good deal of lateral motion; and, in such feet, is liable to be sprained. Another joint runs across between the bones of the *tarsus* and those of the instep. An accurate knowledge of these joints is necessary to the surgeon; for in those severe accidents which are constantly occurring to the labouring population, where a part of the foot is crushed, he is often enabled to preserve a useful foot, by cutting away the injured part, at one of those joints, leaving still the heel to rest upon, and an artificial apparatus is adapted to the stump, to represent the anterior part of the foot. The joints of the toes require nothing particular to be said of them—only that they are similar to those of the fingers, but much smaller. In persons who drink much wine, they are apt to become affected with gout; and in elderly people, the joint at the ball of the great toe is apt to be drawn, so as to make an ugly projection on the inner side of the foot—become exposed to pressure from the shoe, and so produce a corn, which, from its situation, is incurable.

The most common disease of joints is their inflammation. Sometimes this is acute, as after injuries, or from rheumatism. The synovial bag becomes inflamed, and forms an inordinate quantity of fluid, which distends the joint enormously. It is accompanied with intense redness and acute pain, and requires bleeding and other such treatment, to reduce it. In scrofulous persons, the inflammation does not assume this acute form, but is low and long-continued; the synovial membrane forms purulent matter, instead of merely an increased quantity of its natural secretion; the matter gradually works its way to the surface, making one or two ulcerated openings, leading directly into the joint; and, by and by, the cartilages are destroyed—so that, if a probe be introduced, the ends of the bone are felt to be bare and rough. In this state the patient's general health suffers much; he becomes affected with shiverings, profuse night-sweats, and purgings, and unless the limb were amputated, he would speedily die. In the cases of the shoulder and elbow, an operation has come much into use within the last twenty years, by which an incision is made through the skin, and the diseased ends of the bones cut out; a new false joint forms, and the use of the limb is, in a great measure, recovered.

MATHEMATICS.

CHAPTER IX.

ABBREVIATIONS IN THE MULTIPLICATION AND DIVISION OF DECIMAL FRACTIONS.

The rules already given for the operations of multiplication and division of decimals, are generally applicable; but it frequently happens that the work is more laborious than is necessary to obtain the degree of accuracy which the results are required to have. Thus, supposing it is required to find the product of 5·247 multiplied by 3·365, true to two places of decimals only, the rule given does not furnish us with any other mode of proceeding than that of making the full multiplication, and afterwards abridging the result. The actual result is

$$5·247 \times 3·365 = 17·656155,$$

which, made true to two places, is 17·66. Here, then, we have found four places of decimals more than were wanted.

It might, at first sight, appear that this superfluous labour might be somewhat abridged, by abridging our multiplicand and multiplier previous to making the multiplication. Were we to attempt such a modification of the process, it would be at the expense of accuracy. Thus, supposing we reduce our factors by one place each, and make the multiplication, we then have

$$5·25 \times 3·37 = 17·6925.$$

Here we have still two places more than are wanted; and, what is more, the second place is incorrect. The reason of this is very obvious. The error introduced by taking 5·25, instead of 5·247, has been taken 3·37 times, and the error made by taking 3·37, instead of 3·365, has been taken 5·25 times; and the product, 17·6925, contains the sum of these multiplied errors. The sum of these errors is ·036345,* which, taken from 17·6925, leaves 17·656155, the product found by the first process. But we have only been able to make the correction by a knowledge of the original errors.

This mode is, then, both laborious and deficient in point of accuracy. To replace it by a rule which has neither of these defects, it is, however, necessary, in the first place, to premise that in any case of multiplication, we may write the figures of the multiplier in a contrary order—(for example, 1635, instead of 5361)—provided that, in the operation, we move each line one place to the right instead of moving it to the left. This is shown in the following instance, in which the operation is given at full length, according to both methods:

Common Method.	With Multiplier inverted.
31215	31215
5361	1635
31215	156075
187290	93645
93645	187290
156075	31215
167343615	167343615

The results are here the same; and the reason is at once obvious, from an inspection of the two processes.

Suppose now that we wish to multiply 5·247 by 3·365, in such a way as to obtain a product correct to two places of decimals, we have only to apply this principle, taking care to place that figure in the reversed multiplier, which occupied the unit's place, immediately under the second place of decimals in the multiplicand. The process is written below.

5.247	
5633	
1574	1
157	41
31	482
2	6235
17·65	6155

Here we have cut off, by a vertical line, the four places of decimals which are not wanted in the result. But it is very plain that had we neglected these figures entirely, our product would have been faulty; for, looking at the first column on the left of the vertical line, we find 4, 7, 1, 2, of which the first figure, 4, comes from† $4' \times 3''$; the 7, from $2' \times 3''$; the 1, from $5' \times 6''$; and the 2, from $0' \times 5''$—together with the carriage from the preceding multiplications. Were it not, then, that there are certain figures to be carried from right

* This is not strictly the sum of the errors referred to, but the real amount of error committed—which, expressed generally, is $A\,a + B\,b - a\,b$, where A and B are the altered factors, and a and b the errors of alteration. As a and b are, however, very small, $a\,b$ may be neglected, since it must be greatly smaller than either a or b. Thus, in the example, $a = ·003$ and $b = ·005$; therefore, $a\,b = ·000015$. The following is a very simple rule for judging how far a product obtained from two contracted factors can be relied upon. Thus, taking A and B as the factors, if they are true to only one decimal place, then their product is within $\frac{A + B}{20}$ of the truth; if they are true to two decimal places, then the product is within $\frac{A + B}{200}$; if to three, within $\frac{A + B}{2000}$; and so on. Thus, taking the values of A and B, in the example, which are true to two places, we have $\frac{5·25 + 3·37}{200} = ·0431$, for the possible error in their product, 17·6925; so that the true answer must be between $17·6925 - ·0431 = 17·6494$, and $17·6925 + ·0431 = 17·7356$; but at what point the rule does not enable us to determine.

† The ′ means that the figure over which it is placed is in the multiplicand, and ″, that is in the multiplier.

to left of the vertical line, we might proceed with the multiplication, commencing always with that figure of the multiplicand which is immediately over the figure of the multiplier, taking no account of those to the right. But we may observe, from the example, that it is necessary to consider, both what is carried directly in the formation of the different lines and what is carried from the addition of the first column on the right. Now, the first of these may be allowed for, by carrying the tens which result from the multiplication of the figure immediately on the right of that above the figure of the multiplier ; and both corrections may be allowed for at once, by taking the nearest number of tens in that product ; that is, by carrying 1 from 5 up to 15 ; 2 from 15 up to 25 ; 3 from 25 up to 35—and so on. Thus, for 24, we carry 2, but for 26, we carry 3—because 24 is more nearly 2 tens than 3 tens, and 26 is more nearly 3 tens than 2 tens. We shall now write the example in this abridged form, with the explanation of the several steps upon the right.

5·247 5633	Multiplier reversed ; units' figure falling under second decimal place of multiplicand.
1574 -	Product by 3 ; figure to begin with 4 ; but 3 times 7=21 ; nearest tens 2, which carry to 4×3 making 14 ; put down 4 and carry 1 ; the rest as usual.
157 -	Product from second 3 of multiplier ; figure to begin with 2; figure to carry 1 from 4×3; rest as usual.
31 -	Product from 6; figure to begin with 5; figure to carry 1 from 2×6; rest as usual.
3 -	Product from 5 ; figure to begin with 0 ; carriage figure 3 from 5×5. This is equally near 2 tens and 3 tens ; but we at once see that, by going back another step, we would have obtained a carriage of 1 making 26.
17·65	

It will here be observed, that our rule has failed to give us the nearest possible value of 5·247 × 3·365 to two places of decimals, a nearer approximation being 17·66. The error is, however, very small, and if greater accuracy be required than the rule ensures, it may be obtained by finding a decimal place more than is wanted, and striking it off after the addition is made. The rule, then, may be stated as follows :—

To multiply two decimals together retaining only n decimal places—

I. Reverse the multiplier, striking out the decimal point, and place it under the multiplicand in such a way that what was its units' figure shall fall under the nth decimal place of the multiplicand, placing ciphers, if necessary, on the right of the multiplicand, so that every figure of the multiplier shall have a figure or cipher above it.

II. Multiply, as usual, with this difference, that each figure of the multiplier must begin with the figure of the multiplicand which comes immediately over it, taking care to add to the product the nearest number of tens which would be obtained by the multiplication of the figure immediately on the right of that taken.

III. Place the first figures of all the lines under one another ; add as usual, and mark off n places from the right for decimals.

The following examples will fully illustrate this rule. The first two lines are the multiplicand and multiplier, and the number of decimal places to be retained will be seen from the results.

36·3771	·0699268	3·4641016
9·99339	·9975641	17·32508
363771	·0699268	346410160
933999	14657990	8052371
327394	629341	346410160
32739	62934	242487112
3273	4894	10392305
109	350	692820
11	42	173205
3	3	2771
363·529	·0697564	60·0158373

Division admits of a simplification analogous to that explained for multiplication. Thus, supposing 320·31768 is to be divided by 93·4525, and only six places of decimals be required—we proceed as follows :—

Having found the two first figures 3·4 in the usual manner, we suppress the right hand figure 5 of the divisor instead of annexing a cipher to the remainder, as in the common process. To find the next partial quotient 2, we have therefore for dividend 257918 and divisor 93452, with any carriage which may arise from the suppressed figure 5. The operation gives us, for the next remainder, 71013, which is to be divided by 9345 for the next partial quotient 7. This gives us a remainder, 5597, to be divided by 934 for another quotient figure 5. And so on. As in multiplication it is necessary, each time, that a figure is neglected from the divisor to add to the following product the tens which that figure would have given. The process may now be put into the form of a rule thus—

934525)	3203176·8	(3·427599
	2803575	
	3996018	
	3738100	
93452	5)257918	
	186905	
9345	25)71013	
	65416	
934	525)5597	
	4673	
93	4525)924	
	841	
9	34525)83	
	81	
	934525)2	

To divide one decimal by another retaining only n places of decimals in the quotient.

Proceed one step in the ordinary division and determine what part of the quotient the figure is which is thereby found. Proceed in the ordinary way until the number of figures remaining to be found be at least one less than the number of figures in the divisor ; then, instead of annexing ciphers in the ordinary way, abridge the divisor one figure at each step, taking care in multiplying the abridged divisor to carry the *nearest ten* from the figure which is struck off. Repeat this operation, striking off at every successive step one figure from the divisor until no figures are left; then, since it is known, from the first, in what place the first figure of the quotient is, and also how many decimal places are required, we can tell from the beginning, how many figures there will be in the whole quotient. Should the divisor contain more figures than are wanted in the quotient they may be struck off before commencing the division ; and if there be ciphers on the left of the divisor they may be omitted, taking care to move the decimal point of the quotient as many places to the right as there were ciphers struck out.

The following examples will fully illustrate the rule. The quotients are written beneath each, to save room, and the number of decimal places required is marked over each example.

Dec. places,	3	9	8
Divisor,	·31015	1·60021	3·14159265
Dividend,	361·25000*	·138597	1·00000000
	310 15	1280168	94247779
	51100	105802	5752221
	31015	960126	3141593
	200850	97894	2610628
	186090	960126	2513274
	3101 5)14760	18814	97354
	12406	16002	94248
	310 15)2354	2812	3106
	2171	1600	2827
	31 015)183	212	279
	155	160	251
	3 1015)28	52	28
	27	48	27
	1	4	1
		3	
Quotient,	1164·759;	·086611132 1	·31830989

* The ciphers are here annexed to reduce the dividend to the same denominator as the divisor: this enables us to see at once the value of the first quotient figure.

nothing more than masses of metals of different kinds disguised by oxygen; that they are in fact oxides, and bear evidence, in many cases, of being the products of combustion.

ANATOMY AND PHYSIOLOGY.

CHAPTER XIII.

THE CIRCULATION.

In all living bodies, not too minute for us to dissect, we find that there is a vital and highly nourishing fluid distributed all over the body, and penetrating into the intimate structure of every part, on the presence of which life in a great measure depends. This fluid is the blood.

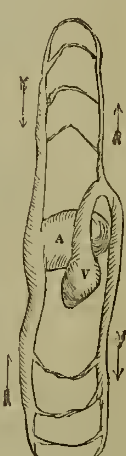
The blood in man is of a beautiful rich crimson colour: it is not so however in all living creatures, for in many at the lower end of the scale, it is white or colourless. In the *mammalia*, birds, reptiles, and fishes, it is red; and in the other classes of animals, with a few exceptions, it is colourless. Hence arose the mistake, which was so long committed, of supposing the lower classes to be altogether destitute of a circulation. Its colour varies also in different parts of the body. In the minute vessels, which are like hairs, and hence called capillaries, it is colourless, because into these the red globules are too large to penetrate; in the arteries it is vermilion; in the veins of a strong crimson purple; and at the right side of the heart it is almost black. It feels thick and unctuous between the fingers, and has a slightly saline taste. In regard to its heat, it varies; in some creatures being warm, and in others cold; in man, its heat near the heart is 98° by Fahrenheit's thermometer.

When examined by the microscope, blood is seen to be composed of an infinity of red globules, of extremely minute size, floating in a thin transparent yellowish fluid; and when drawn into a cup, these parts spontaneously separate; the red globules coagulating into a firm elastic clot, while the *serum* (so called from resembling whey) becomes clear and of a yellow colour. The clot is principally composed of an animal matter called fibrin, which, it has been already stated, is the principal constituent of the muscles. The red colour is not a necessary quality of this substance, for it can be washed out, leaving the fibrin almost white: it depends, according to some chemists, on a small quantity of iron which exists in the blood, and according to others, on a peculiar colouring principle, different from anything existing elsewhere. The *serum* consists of water, holding in solution many salts, of which the two most plentiful are common salt, and the phosphate of lime, which has been already spoken of as forming more than half the weight of the bones. The description of the blood-globules has occupied a number of clever and patient investigators, but the results they have arrived at, are by no means satisfactory. The latest authority gives their diameter as $\frac{1}{325}$ of a line, a line being the 12th part of an English inch.*

The proportion of the fluid to the solid part of the blood is nearly that of four to one, as minutely stated in the accompanying table, yet from this small quantity of solid matter the wants of all the various parts of the body are supplied. It is generally believed now, that the component parts of all the different solids and fluids of the body exist already formed in the blood, and that in the course of its distribution, these are merely separated from it, and arranged in new combinations. This subject will be more fully examined under the head of secretion.

For the purpose of sending the blood all over the body, there are a set of tubes everywhere distributed, which are called the Arteries; and to drive the blood through them, there is an organ similar in its action to a syringe, which is called the Heart. The heart with its system of arteries is exceedingly like the system of pipes through which the water is distributed over a city: an immense mainpipe runs along the principal street, from which less ones run up the smaller streets, and these smaller ones again give off the smallest pipes which supply individual houses. The water is driven through them by an immense forcing-pump, wrought by a powerful steam-engine. In the human body, the heart represents the pump; the *aorta*, or great artery, represents the mainpipe, which gives off a number of primary branches; these again give off a certain number of secondary ones; and these divide into an infinity of minute ones, millions of which are invisible to the naked eye. And as each house in the city receives a pipe to bring water for its use, so in the body, each part receives its branch, each minute granule its twig, so that all may participate in the enjoyment of the life-giving fluid.

There is, however, a set of tubes in the circulation, which we do not see in the water-system of a city. There, if the water be used, it is allowed afterwards to run to waste. But in the body, after having vivified the parts by its presence, and deposited what was necessary for their growth and repair, the remaining quantity, not greatly diminished, is brought back again to the heart by the veins. Having been sent over from the heart through the arteries, and returned again through the veins, the blood is said to have "run through the circulation."



In this figure, we have a plan of the simplest idea of the circulation, as performed by a single heart. V, represents the *ventricle* or strong muscular bag of the heart, which, when filled with blood, contracts upon it, just as any other muscle does, and so forces out the contents through the pipe which arises from it, called the aorta, just as you squeeze the contents of an India-rubber bag out through a pipe fixed into its neck. The only difference is, that whereas an external force squeezes the bag, the heart, being muscular, has a power of contraction of its own; if the expression be allowable, it squeezes itself. And then, just as the India-rubber bag regains its shape when you take off the pressure, so the heart, when it has squeezed out all the blood, dilates itself again, and is ready to contract anew. It is this alternate contraction and dilatation which constitutes the beating of the heart.

The blood having been poured into the great artery, goes through branches up to the head, and down to the lower part of the body, where its minute or capillary terminations are seen to end in veins. Those from the lower part of the body form an inferior great vein; those from the upper a superior; and the two veins terminate separately in a bag A, called the *auricle*. The *auricle* is not nearly so strong as the ventricle, because it has nothing to do with forcing the blood over the body; it is intended merely as a receptacle for the venous blood, till the ventricle be ready to receive it. Its name is derived from a Latin word signifying the hanging part of the ear, because a portion of the edge of it is exceedingly like a dog's ear. The auricle is constantly full of blood, which flows to it through the veins in an equable stream; so that whenever the emptied ventricle dilates, the blood from the auricle rushes in, and distends it for a renewed contraction.

But the arteries are not a set of rigid tubes; they are dilatable, and highly elastic. Hence at the moment when the ventricle contracts, the blood which is forced into them

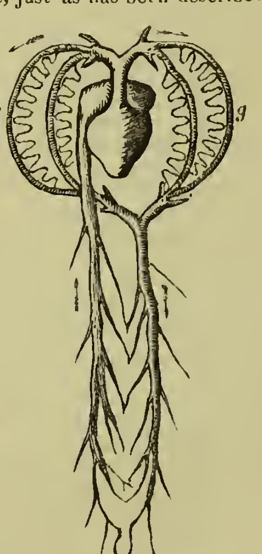
* Lecanu's analysis of the blood is as follows:—

Water,	786·500	Chlorides of soda and potass, alkaline, phosphates, sulphates and subcarbonates	7·304
Albumen,	69·415	Subcarbonate of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron,	1·414
Fibrin,	3·565	Loss,	2·586
Colouring matter,	118·626		
Crystallizable fatty matter,	4·300		
Oily matter,	2·270		
Extractive matter, soluble in alcohol and water,	1·920		
Albumen, combined with soda,	2·100		1000·

distends them, increasing their diameter, and producing the feeling communicated to the fingers placed over them, which is called *the pulse.* The number of the pulse is therefore the number of contractions which the heart is making in a minute. And at the moment when the ventricle dilates, the artery, having the distending force taken off, contracts on its contents. It would now drive part of the blood back again into the ventricle, were it not for a valve placed in the artery at its origin, which shuts down the moment the pressure comes on it backward, so that the force of the elasticity of the artery is expended in propelling the blood forward, not in an equable stream, but in successive waves. Hence when an artery is cut, the blood does not flow from it evenly, as is seen when a vein at the bend of the arm is opened, but in jets. Again, when the ventricle contracts to throw its blood into the aorta, it would throw back an equal portion into the auricle, were not a valve placed there also, wl 'ch shuts the moment the ventricle contracts. The valves are named from their situation, the first being the *aortic*, and the second, the *auriculo-ventricular.*

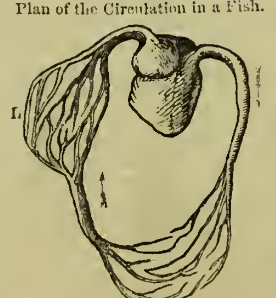
If the blood could be constantly circulated in the same state, this simple apparatus would suffice. But in passing through the circulation, it acquires certain impurities, derived from the wearing out of the parts through which it passes, and it is requisite that these should be got rid of, before it is permitted to make another circuit. For this purpose it is brought into contact with the air in the lungs, so as to be purified, and be changed from the dark purple colour which it acquires in its passage over the body, and be brought back again to its original scarlet. This is done in several different ways; in some creatures by a modification of the heart, in others by a change in the arrangement of the arteries and veins.

In fishes, the heart is single, just as has been described. The aorta, before giving off any branches to the body, divides into two branches, one to each side, and each of these subdivides into four, one for each plate of the gills. Two of these on each side are cut off in the figure, lest it should appear confused. In the gills, the blood is exposed to the chemical action of the air, which is constantly mingled with the water. Afterwards, these branches reunite into a trunk, which then subdivides to supply the different parts of the body. It is plain that a fish's heart is constantly circulating venous or impure blood.



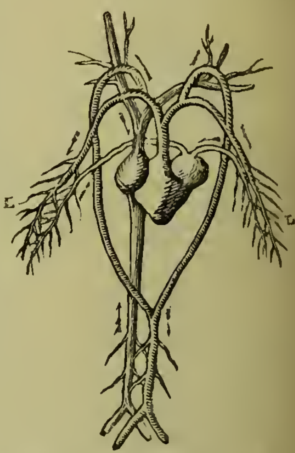
Plan of the Circulation in a Fish.

In the crab and lobster, the heart is single too, but it circulates pure or arterial blood. The blood passes from the heart to the body, then is collected, in an impure state, into a vein, which again subdivides and allows it to reach the lungs, whence it returns in a pure arterial state to the auricle, and is ready to be sent out by the verticle afresh.



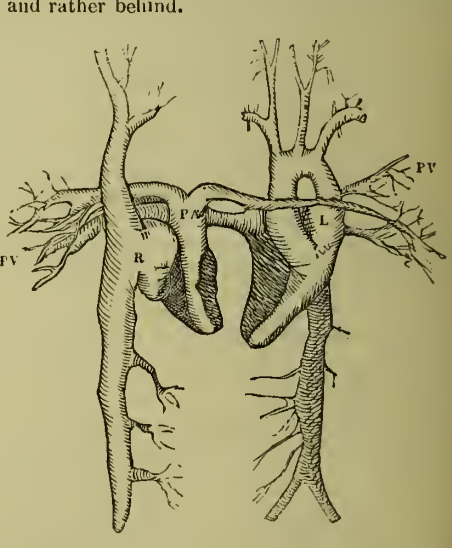
Plan of the Circulation in a Crab.

In amphibious animals, such as the frog, the circulation may be said to be less perfect, inasmuch as the whole blood is not purified between the times of its being sent over the body; and yet the heart is more complicated, being provided with an additional chamber. The great artery is seen to divide into a right and left branch, each of which again divides, giving a branch to the lung, and a branch to the body. The impure blood from the body returns into a right auricle by two great veins, and the pure blood from the lungs comes into a left auricle by a vein from each lung, and then the two auricles pour their contents into one common ventricle, so that the blood sent over the body is neither so pure as what was in the left auricle, nor so impure as what was in the right. A low degree of purity would seem to be sufficient for the wants of these animals.



Plan of the Circulation in a Frog.

In man, and all warm-blooded animals, there are two distinct hearts, one for the lungs, and one for the system, a pulmonary and a systemic heart, one for the purple blood, and one for the scarlet. They are united together so as to form one organ, that they may take up little room, and act simultaneously, the one contracting and dilating at the same time exactly as the other; but still they are quite separate in their cavities, having no communication between them, except the circuitous one round through the lungs. In man, the pulmonary heart is placed to the right, and rather in front, the systemic one to the left, and rather behind.



In the accompanying figure, the double heart is represented as separated into its right and left portions.* The right heart R, is seen with its two great veins, an upper and a lower, entering the right auricle. Below the auricle is seen the ventricle, from the upper part of which the pulmonary artery, P A, arises, and divides into two branches, one for each lung. The blood having passed through the lungs, is collected by the pulmonary veins, P V, and poured into the left auricle L, from which it reaches the left ven-

* In the Dugong, an animal somewhat like the seal, the right and left portions of the heart are separated nearly as much as in this imaginary figure.

tricle, and is by it sent over the system through the aorta. The aorta A is seen to rise first, and make an arch, from which three large branches go off, supplying the two sides of the head and the two arms; and then it goes down through the belly, giving branches to its contents, and dividing into two terminal branches for the lower extremities. We have here, then, two circulations going on at once, the lesser, or pulmonary, and the greater, or systemic.

In the real body, the two hearts are joined, so as to form a single organ. The right ventricle lies more in front, and a hollow line passing obliquely from the base towards the apex, separates it from the left. The left ventricle is longer and narrower than the right, and its point forms the apex of the heart. The right auricle is seen at the base of the heart, when in its natural place, while only a small portion of the left, that part which is like a dog's ear, is visible. Rising from the centre of the base of the heart, is the aorta, or great artery of the system; on the left side of this is the pulmonary artery, or that for carrying the impure blood to the lungs, and on the right side is the great vein of the head and upper extremities. Below, the great vein of the lower part of the body is seen, passing up to enter the right auricle. The pulmonary veins are two on each side, bringing the blood from the two lungs into the left auricle.

In examining the interior of the heart, it is most convenient to follow the course of the circulation. If the right auricle be opened, it will present the two orifices of the great veins, and they will be found not to enter opposite to one another, but obliquely, in order that the two currents of blood may not strike one another directly, and so impede one another from entering. On the partition between it and the left auricle is a hollow, marking the place where before birth there was a direct communication between the two sides of the heart. Each of the great veins is large enough to admit a man's thumb, and the auriculo-ventricular orifice, or hole leading from the auricle into the ventricle, will easily admit three fingers. The right ventricle is thin in its walls, because it has to force the blood only through the lungs; in general it is about a quarter of an inch in thickness. There are three valves in the auricular opening, whose edges are fixed to a number of tendinous threads, preventing them from being pushed back into the auricle by the pressure of the blood upon them at the time of the ventricle's contraction. No drawing can give any idea of these valves, so a figure of them has not been inserted. The orifice of the pulmonary artery is guarded by three valves also, to prevent regurgitation into it while it is dilating, and being filled from the auricle.

The left auricle has four openings leading into it, of the four pulmonary veins, two from each lung. The auriculo-ventricular orifice is smaller than that on the right side, admitting only two fingers. The left ventricle is three times thicker and stronger than the right, because it has the much harder duty of propelling the blood all over the body. The valve between it and the auricle has only two flaps, similar to those on the right side; and the orifice of the aorta has three, similar to those in the pulmonary artery, but stronger, on account of the greater force which they have to resist.

The outside of the heart is covered with a smooth shining membrane, which enables it to glide in a bag in which it is placed, called the *Pericardium*. This bag is lined with the same membrane which covers the surface of the heart, so that both surfaces being moistened constantly by a watery exhalation, the friction may be lessened almost to nothing. Occasionally the water becomes collected in considerable quantity, causing dropsy of the pericardium, and sometimes the inside of the bag becomes inflamed, and the two surfaces grow together,—an unnatural state, which, if it do not produce death at the time, generally brings on disease of the heart at an after period, by reason of the impediment which it gives to its motions. The outside of the bag is placed upon the upper surface of the diaphragm, or floor between the chest and belly—its back part is in contact with the spine—its front is touching the breast-bone and ribs, and its top is nearly at the root of the neck. The heart extends from the third to the seventh rib on the left side, and its point is felt beating at two inches below the left nipple, and an inch nearer the breast-bone. It is of importance to have these limits accurately marked out, because they enable us readily to detect any changes produced by disease.

If the ear be applied to the chest over the heart, either immediately, or with the intervention of the wooden instrument called a *stethoscope*, certain sounds are heard, produced by the heart in its action. The French denote them by the word *tic-tac*, which represents them pretty accurately. The first sound is heard at the time when the ventricles contract and strike the ribs; the second, of a sharper and more abrupt character, is heard when they dilate. The medical man requires to be well acquainted with the natural sounds of the heart, that he may be able to detect any changes produced by disease. When the valves become ossified, and the openings contracted, various curious sounds are heard, resembling the blowing of a pair of bellows, the rasping of a file, the purring of a cat, the cooing of a dove, each of which is now ascertained to indicate a particular form of disease.

Besides the disease of the valves of the heart, there may be alterations taking place in the muscular substance. Sometimes the cavities of the heart become dilated, or much larger than they should be, and consequently weaker; and sometimes the walls become much thicker and stronger, so that the blood is circulated with unusual force. These conditions generally bring on dropsy, and the last often produces apoplexy; and they are usually accompanied by palpitations, which are just irregular beatings of the heart. Palpitation does not, however, always indicate disease affecting the structure of the heart, but is frequently nervous, depending on weakness from loss of blood, or other causes, or on disorder of the stomach, or even on mental emotion. We often hear a broken heart spoken of; yet, though common enough in a figurative sense, it is in reality a very rare occurrence. The author has, however, in his museum, the heart of an elderly man, which affords a real specimen of this accident. The heart was much dilated, and one night the patient died suddenly. On examination, the left ventricle of the heart was found burst; the hole admitted a large quill, and the pericardium was found completely filled with the blood which had escaped. The heart is generally about the size of the fist of the owner; at least that is an approximation which enables us to judge of it, on opening a body, whether it be natural, enlarged, or the reverse.

GEOLOGY.

CHAPTER XI.

SILURIAN SYSTEM.

Geology had made considerable progress, and names had been assigned to the various systems of stratification, before the Silurian rocks* were brought into that notice which their great importance demands. The primary schists were followed in the geological nomenclature by the transition or the greywacke rocks—strata in which organic forms were considered as developing their earliest existence. We owe it, however, to the united labours of Professor Sedgwick and Mr Murchison to have rescued these rocks from comparative oblivion, and to have placed them in that prominent position which the phenomena they present entitle them to hold.

In our last article, we described the nature of the Cambrian or slate rocks, and noticed what may be termed the first introduction of animal existence into our planet. The want of organic remains in the Scottish schists and greywackes was alluded to,

* It may be observed, that the most eminent of our systematic geologists have lately proposed to subdivide the English sedimentary strata below the old red sandstone, into two leading groups, the lower of which is the Cambrian, already described, and the upper or newer group, to which Mr. Murchison has applied the name of Silurian, because these rocks are most fully developed in that part of England and Wales which was included in the ancient kingdom of the Silures.

and their extraordinary mineral development. In Scotland, the truncated edges of the schists are almost everywhere overlaid by old red sandstone, and we have no really authenticated representations of the Silurian rocks of Shropshire and the adjacent counties of Montgomery, Denbigh, Carmarthen, and Pembroke, though such occur in Ireland, and on various parts of the continent of Europe, and in the United States of America.

Regarded as an aggregate, the rocks of the Silurian system are less slaty than those of the older schist, and consist of freestone, flagstone of various colours, calcareous sandstone, argillaceous limestone and shale, and average from 7000 to 8000 feet in thickness.

These rocks have been divided into four groups, named according to the places where the prevailing characters of each formation is most perfectly exhibited—namely, the Ludlow, Wenlock, Caradoc, and Llandeilo rocks. These form what are termed the upper and lower Silurian rocks, and their characters and order of succession are explained in the following table:—

UPPER SILURIAN ROCKS.

Formations.	Members.	Prevailing Lithological Characters.	Thickness.	Organic Remains.
Ludlow.	Upper Ludlow.	Micaceous grey sandstone.	feet. 2000	Marine molluscs, of almost every order, the Brachiopodous most abundant. Serpula, Corals, Sauroid fish, Fuci, (sea-weeds.)
	Aymestry limestone.	Argillaceous limestone.		
	Lower Ludlow.	Shale, with concretions of limestone.		
Wenlock.	Wenlock limestone.	Concretionary limestone.	1800	Marine molluscs of various orders as before. Crustaceans of the Trilobite family. No vertebrated animals or plants
	Wenlock shale.	Argillaceous shale.		

LOWER SILURIAN ROCKS.

Formations.	Members.	Prevailing Lithological Characters.	Thickness.	Organic Remains.
Caradoc.	Caradoc sandstones.	Flags of shelly limestone and sandstone, thick bedded white freestone.	2500	Crinoideans, Corals, Molluscs, chiefly Brachiopodous, and Trilobites.
Llandeilo.	Llandeilo flags.	Dark coloured calcareous flags.	1200	Molluscs and Trilobites.

In describing these, we shall, according to our usual method, proceed from the lower to the higher strata, that we may the more effectually convey to the reader that clear and distinct view of the operations of Nature, whilst introducing organic existence into our planet, which is one of the great objects of these papers.

In the Cambrian or slate rocks only a very few fossils have been discovered, perhaps not more than thirty species. "It may surprise," says Professor Philips, "the speculators in cosmogony to hear, that these, the most ancient forms of life known to us, should not be plants, but animals; not merely zoophytes, but conchifers; not the lowest grades of their respective classes, but perfectly developed lamelliferous zoophytes and brachiopodous molluscs. Whether at the time of the formation of these ancient rocks in the sea, plants were growing on the land; whether indeed there were any land, we must not even conjecture; that plants might be growing in the sea which nourished the shells and zoophytes of Snowdon, is a probable but not a certain inference, since seaweeds do not alone constitute the food of conchifers and zoophytes." We shall now notice the different members of the system in their order.

1. The lowest member of the Silurian system, the Llandeilo flags, consist of hard, dark, gray-coloured flags, often calcareous in their composition, together with sandstone and arenaceous or clay schists, with veins of calcareous spar. It is in this portion of the Silurian rocks, where the trilobites make their first appearance, a family of extinct crustaceans, the history of which tends to throw considerable light on the ancient condition of our earth. Of these singular creatures, the Llandeilo flags present us with five genera comprehending 11 species.

2. The Caradoc sandstone appears in large mountain masses in the counties of Montgomery and Denbigh. In Carmarthenshire there is a singular tract which exhibits some very extraordinary contortions of the strata of this portion of the system, which is readily determined by the great abundance of pentameri and other characteristic fossils; "while the proofs of plutonic action appear in the existence of planes of cleavage, distinct from, yet nearly resembling those of, stratification, and in some cases, even cutting through the organic remains. These cleavage planes are always parallel, while the surfaces of the beds are often curved. There is no spot indeed, Mr Murchison remarks, in which the distinctions between cleavage and joints are better defined than in this rugged tract." "It is facts like this," continues a writer in the *Edinburgh Review*, "which lead us to doubt whether some of the slaty masses now called Cambrian, may not have been originally Silurian rocks, in which the characters have been either wholly or in part defaced by plutonic action." The organic remains of the Caradoc sandstone are much of the same character as those of the Llandeilo flagstones.

3. *Wenlock Shale.*—This formation consists of clay-shale of a dull gray, or olive colour, containing concretions of earthy limestone. The only crustaceans in this formation are the Asaphus caudatus, and Longi caudatus, two new species: the first is figured on the margin.

A. Caudatus.

4. The Wenlock limestone ranges in Shropshire for about twenty miles from south-west to north-east, with the escarpment of the Aymestry limestone running nearly parallel to it at the distance of about a mile. Both limestones are prominent while the intervening shales have been denuded owing to their greater softness. This limestone and that of Dudley are equivalent. It consists generally of large concretionary masses of pure limestone, frequently crystallized into calcareous-spar, denominated "ball-stones," which are separated by intervening layers of coarser dullish-gray calcareous matter, called "measures." The spar is commonly white, but sometimes of a beautiful pink colour. The "ball-stones" are sometimes thirty feet in diameter, and are used as a flux at the adjoining iron-works. The Wenlock and Dudley limestones are remarkable for the number of coralline remains which they contain. Of these 35 genera, comprising 70 species, have been described. The multitude of these remains—which are also common to the contemporaneous limestone of Eifel—together with their mode of aggregation, have, indeed, suggested the notion of these rocks being in fact ancient coral reefs. Perhaps the most abundant and characteristic of the organic forms exhibited is the chain-coral, called systematically *Catenipora escharoides*.

Catenipora Escharoides.

5. *The lower Ludlow Rocks.*—These form the basis of the upper Silurians, and consist of sandy shale and flags of a dark-gray, or liver colour, with concretions of earthy limestone. It is in these beds where the remains of fishes are first found. Trilobites also occur in this and in the two superior members—namely, the Aymestry limestone, and upper Ludlow rock.

6. *Aymestry Limestone.*—The limestone measures generally about 50 feet in thickness, and is of an argillaceous subcrystalline character, and of a blue or deep gray colour. It forms an excellent cement under water.

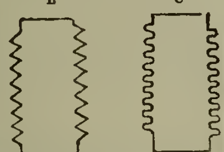
7. *Upper Ludlow Rock.*—This member consists of thin beds of soft subcalcareous sandstone; gray and greenish, sometimes passing into limestone, but near the top scarcely distinguishable from the lower beds of the old red sandstone, except by its fossils. These beds are seen emerging from beneath the old red sandstone strata along a zone or band, extending from the hills near Ludlow, on the north coast, to the sea cliffs at the south-west extremity of Pembrokeshire, a distance of about 150 miles. The *Lingula cornea* is common to the upper part of this groupe, and to the lowest or tilestone beds of the old red sandstone, and a short distance below the junction is a stratum of great interest from its abounding in the confused remains of fishes, which Dr Lloyd of Ludlow was the first to discover and bring into notice. The remains in the central portion of the upper Ludlow are unusually perfect. In the fine argillaceous shales, known provincially as "mudstones," from their tendency to dissolve into mud,

ed indefinitely with the same inclination round the axis passing through the centre o. It will be in fact a series of such planes joined end to end, and forming a regular spiral. It is easy to conceive a cylinder passing up through the spiral, upon which it would lie close at every point; and further, conceiving the cylinder and the spiral to be of one piece, we arrive at the ordinary idea of the *external* screw, as here shown. It consists of a square thread cut upon a cylinder, running continuously round it, and always preserving the same angle with the base.

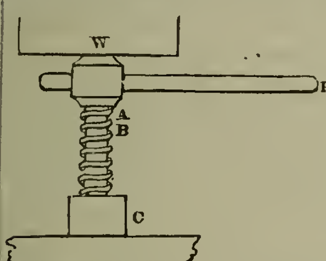
Applying the same idea to the upper plane D E F in the fourth last figure, it ought also to be extended circularly, having the same circumference as the under plane A B C, so that the threads of the spiral formed by it may lie between and upon the threads of that plane. If we also conceive this spiral fitting close *within* a hollow cylindrical space, and forming one piece with the body in which the space is formed, we have a correct idea of an *internal* screw.*

Screws are also constructed with threads, of which the cross section is triangular, and others have circular sections, as at B and C. According as the threads are formed, the screw is termed square-threaded, angular-threaded, or round-threaded.

B C



Whatever be the form of the thread, the longitudinal distance between corresponding points in contiguous threads of a screw is termed the pitch of that screw. For instance, in the annexed sketch of the screw of a screw-press, the distance A B between the same sides of two threads is the pitch; and it is evidently through this height that the weight W is raised during each revolution of the point P to which the power is applied. This height is in fact that of the plane of which the thread A B is formed. Now, in reference to the fourth last figure, it was stated that the power P is to the weight W in the same proportion as A B is to the circumference, which the point L, or P in the above figure, would describe in one revolution. On this principle, therefore, the power of the screw may be calculated.



Suppose, for example, the distance between two threads, A B, of the screw, is one inch, and the circumference which the point P would describe in a whole revolution would be nine feet, or 108 inches—the length from P to the centre of the screw being about three feet—then a pressure of *one* pound at P, would sustain 108 lbs. at W.

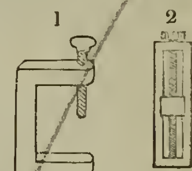
The friction of the parts of a screw is, however, so great, that, in practice, the effect falls far short of the calculated effect.

It is not to be supposed that the screw is solely applied to the raising of weights through considerable heights. The screw is employed to overcome every variety of resistance, and to communicate sustained motion in any direction. For example, in Whitworth's planing machine, the table receives its alternate longitudinal motion from a revolving-screw; and by the same means the slide-rest of his self-acting lathe is moved along its bed.

* The external and internal screws are otherwise known by the appellations of *male* and *female* screws. The coarseness of the analogical derivation of these terms, as well as their being quite unnecessary, ought to expel them from common use.

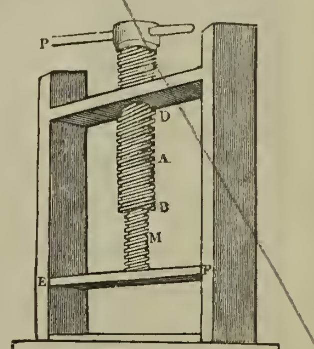
For the purpose of communicating motion to any piece of machinery, the external screw is made of a length necessary to give the required traverse, while the internal screw is generally quite short, embracing half-a-dozen or more threads of the external screw. In this case, the internal screw is termed a nut, and the other is named simply the screw. In their application to machinery, either of them is made stationary in reference to the other, the latter being the one that receives the motion. Thus, in the common screw press, before noticed, the nut C is fixed on the sole of the press, and the screw bears upon it, while rising after the weight W. Again, in the clamp represented at fig. 1, the internal screw is fixed, and the external one moveable; while on the other hand, at fig. 2, which is a sketch of a micrometer screw, it will be noticed that, while the screw is confined by a collar at the neck, the nut slides along the screw between two checks.

1 2



The power in the screw is greater as the inclination of the plane forming its thread is less, and as its radius is less in comparison to the length of the lever at the extremity of which the power is applied. Hence, by lengthening the lever by which the power acts, or by cutting the threads sufficiently fine, the effect of the screw would appear capable of being increased to any extent. It is, however, often practically inconvenient to increase the length of the lever employed; and if the threads of the screw be cut too fine, they become too weak to support the pressure.

To remedy this inconvenience, a contrivance has been invented, somewhat similar to one for a like purpose, described under the "wheel and axle." A screw is cut upon the *outside* of a cylinder A B, and a corresponding *internal* screw is cut in the nut D. The cylinder A B is also hollow, and an internal screw is cut in it, corresponding with an external screw cut upon the cylinder M, which is attached to the sliding part of the press E F.



If the screws upon the cylinders A B and M had just the same pitch, and the upper screw turned by the power P; then as the cylinder M would rise just as much as the cylinder A B would fall, the sliding-board E F would be stationary. But if the pitch of thread on the part M be less than the part A B, then, in each revolution of P, the board E F will be depressed through a space equal to the difference of the pitches of the two screws. It is evident that this difference may be as small as necessary without weakening the screws. And there is an equilibrium when P : W : : as the difference of the pitches of the threads is to the circumference described by P.

Other applications of the screw are made in machinery in the instance of the worm-wheel, and worm or endless screw, in which the screw by revolving, communicates a greatly reduced motion to the wheel.

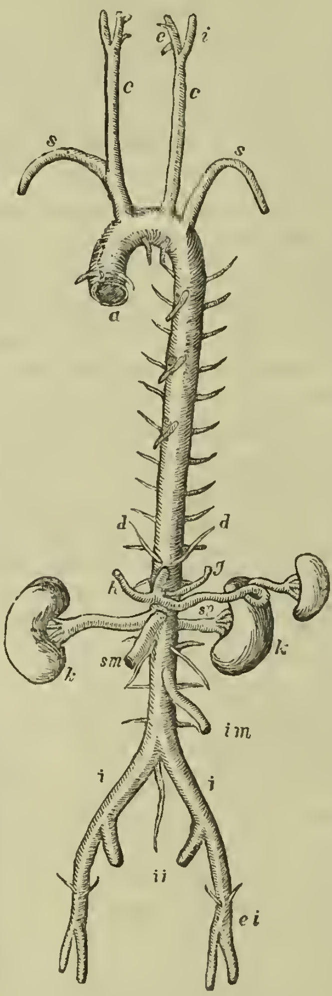
ANATOMY AND PHYSIOLOGY.

CHAPTER XIV.

THE CIRCULATION.—(*Continued.*)

HAVING examined the central organ of the circulation, let us now turn up the conduits by which it pours out its contents, and those by which it is fed.

The *aorta*, or great artery of the system, has been described as arising from the left ventricle of the heart. It passes first upward, then forms an arch across to the left, and passes down along the left side of the spine through the chest, behind the heart. Just where it has been cut off from the heart, three valves are placed which are seen closed at *a*. Their action in preventing the blood from getting back into the ventricle at the moment when it is dilating, and the aorta contracting by its elasticity, has been already adverted to in chap. xiii., at page 428. In this course, it first gives off two small branches for the nourishment of the heart itself; and then generally gives off three great branches to the head and arms. The first of these is the largest, about the thickness of one's little finger, and divides into the artery of the right arm, and the artery of the right side of the head. The second branch is for the left side of the head, and the third goes to the left arm. The concavity of the arch sends off two or three small branches for the nourishment of the lungs; and the descending aorta gives off from its sides a series of small arteries to run below each rib, and nourish the muscles by which the ribs are connected, and from its front, three or four of like size, to nourish the gullet, which lies just beside them. On arriving in the belly, by passing through the diaphragm, the aorta gives branches to nourish that muscle; and then a very large branch which divides into three, to supply the liver, the stomach, and the spleen, called respectively the *hepatic h*, the *gastric g*, and the *splenic sp*, arteries. Next, a large branch runs down through the belly supplying the intestines, the *superior mesenteric sm*, then a large one on each side to the two kidneys *k*, and lastly, a smaller one to the lower part of the great gut, the *inferior mesenteric im*. Upon the fourth lumbar vertebra, the aorta now divides into its two terminal branches, the *iliacs i*, for the two lower extremities, giving off at the same time an artery not larger than a crow quill, which runs down the middle of the rump-bone, and corresponds to the artery of the tail in beasts.



The artery going to the arm, the *subclavian, s,* passes up through the upper orifice of the chest, turns over the first rib, and runs down through the arm-pit. It gives off a large artery to the brain, which runs protected in a curious way through the vertebræ of the neck; and afterwards several branches to the inside of the chest, the root of the neck, and the top of the shoulder. In the arm-pit it gives off branches to the back of the shoulder, and some long ones which run down the side of the chest, supplying, in the female, the breast. The artery of the arm then runs down in a hollow which is seen in the plates illustrating the muscles, between the *biceps* muscle on the forepart of the arm, and the *triceps*, which is seen appearing from behind. We find all the arteries of the limbs running in this way, in hollows between muscles, where they are protected from pressure, and as much as possible out of the way of injury. In this course the artery gives branches which nourish the fleshy part of the arm. In the hollow in front of the elbow-joint, the artery divides into two branches, the *radial* and *ulnar*, running down the fore-arm on their respective sides. The ulnar, besides, gives off a considerable branch which runs down in the middle, for the supply of the deep muscles. It is the radial artery in which it is the practice to feel the pulse, not on account of anything peculiar in the artery, but because it is most conveniently got at. The Chinese have an idea that every different pulse in the body has a different meaning, giving warning of the affection of some particular organ. After what has been said already, it need scarcely be remarked that this is a fallacy, because the pulse must be the same in every artery, as in all it is produced by the stroke of the heart; and all that we can learn from it, is the state of the circulation, whether quick or slow, hurried or languid, regular or irregular, with some minute shades of difference, which, however, give valuable information to the practised finger.

On reaching the hand, the ulna is seen passing in front of the wrist; and, arching to the space between the thumb and forefinger, gives off from the convexity of this arch four *digital* branches. One of these belongs to the inner side of the little finger, and each of the others goes to the division between the fingers, and sends branches along the opposite edges of each, the artery of the one edge communicating freely at the point with the artery of the other edge. The radial artery at the wrist gives off a small superficial branch, which supplies the ball of the thumb, and often communicates with the superficial arch. It then passes out of sight, winding round the root of the thumb, going between the thumb and forefinger, supplying the thumb, the outer side of the forefinger, the deep part of the palm, and communicating with the termination of the palmar arch. These are the arteries which are apt to suffer from knives being stuck into the hand, and though not very large, they bleed very profusely. The radial and ulnar arteries, near the wrist, where they lie superficial, not unfrequently suffer from such an accident as a servant's breaking a pane of glass while cleaning the window; they cannot be stopped by bandages, and must be secured by a surgeon, with a ligature.

The *carotid* artery *c* runs up the side of the neck more than a quarter of an inch in diameter, and just below the angle of the jaw divides into two nearly equal branches, the one going into the inside of the head to supply the brain *i*, and the other being distributed over the outside of the head and face *e*. One branch runs down the forepart of the neck; a second goes into the tongue; a third runs up the face, and encircles half the mouth, meeting with similar branches from the opposite side, which complete the circle in the lips, where it may be felt beating on the inside, by catching the lip between the finger and the thumb. A fourth branch passes to the back of the neck; a fifth to the back of the head; and a sixth to the outer ear. The terminating branches are, one to the throat; one to the deep parts of the face; and one to the temples, where it is felt beating. This last is the only artery which it is permitted to open for the purpose of drawing blood; because it can easily be stopped, by compressing it against the bone on which it lies. It is opened chiefly for affections of the head, as in apoplexy, or in fever. A gentleman, formerly well known in Glasgow, was seized with a fit of apoplexy while standing at a window, against which he fell; the glass cut the temporal artery, and so much blood was lost from it before the surgeon arrived, as to have brought him round.

The *aorta*, it has already been said, bifurcates into the arteries for the lower extremities, called the *iliacs* from the Latin name *ilium*, for the haunch-bone. Each of these again divides into two branches, one of which, *i i*, supplies the parts within the pelvis, and terminates on the buttock, and the other *e i*, passes out over the brim of the pelvis in front, and runs down the thigh, under the name of the *femoral* artery. (Latin, *femur*, the thigh.) The femoral artery gives branches to the great muscles about the hip-joint, and to those on the thigh itself, and then twines round the inside of the thigh to its backpart, where it enters the ham. In the ham, which, it has already been stated, signifies anatomically the hollow behind the knee, it gives off five small branches to nourish the knee-joint, and then divides into the three arteries of the leg. One of these perforates between the bones of the leg to the front, where it runs down, supplying the muscles in this situation, and terminating on the back of the foot; another runs on the outer side of the back of the leg, close to the *fibula;* and the third, which is the principal one, runs down to behind the inner ankle, where it may be felt beating, turns into the sole, and is distributed to the parts there in a manner similar to the palmar arch in the hand, communicating between the first and second toes with the artery on the back of the foot. This artery is liable to be wounded when it lies behind the ankle, as with a scythe, or the blow of an adze slipping from a piece of wood; and the author once saw it cut in a boy, by a sharp stone which another had thrown at him. When wounded, it requires to be exposed and tied like those at the wrist.

The arteries consist of three coats, or layers; an internal one, which is very smooth and thin; a middle one, which is highly elastic, and on which their action principally depends; and an external one, which connects them with the neighbouring parts.

The extreme arteries, or ultimate branches, into which they divide, are said to terminate in four different ways. Many of them terminate in minute pores in the intimate substance of the different parts, to allow the blood to exude, for the purpose of nutrition. Some of them terminate in secreting organs, furnishing blood to be converted into saliva, bile, urine, and so on. Others terminate on exhalant surfaces; that is to say, on the surfaces which are constantly kept moist, such as the membranes of the lungs, and of the belly. Lastly, the remainder, and by far the greatest number, terminate in the commencement of the veins, (as represented in the diagrams in last article) sending back by them the blood which has not been expended in these three ways.

In describing the veins, we must proceed in the opposite direction from that which we have followed in describing the arteries; commencing at the branches, and proceeding along the trunks to the heart. They are much more numerous, and of greater capacity than the arteries, so that the blood moves in them much more slowly. They do not pulsate like the arteries; for the impulse of the heart is nearly lost upon them; and hence, when opened, the blood does not flow from them in jets, but in an equable stream. They consist of two coats, an outer, which is very distensible, so that the vein can swell very much, and an internal one, which is smooth, and in many respects similar to the lining membrane of the arteries. There is one striking difference between them and the arteries, that they have valves placed at distances of an inch or two, which prevent the blood from flowing backward from the heart towards the extremities. Hence is the use of tying a fillet round the arm previous to bleeding; the blood is constantly arriving from below, because the pressure is not great enough to obstruct the arteries; but it cannot get up past the bandage; the veins are therefore distended, and become prominent, so as easily to be seen and punctured; and then, as the blood cannot get down the arm again for the valves, it is necessitated to jet out at the orifice. The veins in the limbs lie in two sets, a deep-seated, and a superficial. The deep set lie alongside of the arteries, there being generally two to each artery: the superficial lie immediately under the skin, and above the fascia or sheath of the limb, and these two sets have every here and there branches communicating between them. Hence, when pressure is made by the muscles on the deep set, the blood escapes into the superficial, and finds by that road a passage to the heart. The reasons why bleeding is done in the veins are twofold,—first, that they are more easy of access than the arteries,—and second, that they heal readily, by the mere application of a bandage.

On the back of the hand, the veins lie above the extensor tendons, escaping the pressure to which they would have been subjected in the palm. They then take their course up the front of the fore-arm, and over the elbow, where one of the largest runs directly over the artery. In former days, when the lancet was used by the farrier and the midwife, the artery was not unfrequently wounded here, through the vein; and serious consequences were the result. This accident is seldom seen now, when medical practitioners are spread all over the country. Above the elbow most of the veins dip deep to accompany the artery, and in the arm-pit the vein is nearly the size of one's thumb. Passing up under the collar-bone, it meets the deep jugular vein at the root of the neck. These two there form a large vein, which meets a similar one of the opposite side, and these, again uniting, form the descending great vein, which pours the blood from the head and upper extremities, into the right auricle of the heart.

On the head a number of veins collect from the scalp, and form a vein in front of the ear,—the temporal vein. Below the angle of the jaw, this receives the vein from the face, and then the one from the tongue, and forms the external jugular vein, in which we are accustomed to bleed in cases of apoplexy. It passes down the side of the neck to the collar-bone, and joins the great vein of the upper extremity. The blood which has been circulating in the brain comes out of the cranium by two large holes, one on each side, and forms the deep jugular veins. These receive the branches from the deep part of the face, and form a vein as thick as one's thumb,—the deep jugular, which lies close to the carotid artery.

The blood of the lower extremities is collected by veins placed on the back of the foot, that they may escape pressure; and from these one large vein passes up the inside of the leg, and another along its back, with a multitude of smaller branches which keep up a communication between them. Besides, there are, of course, two deep-seated veins to each of the three arteries of the leg, all of which unite in the ham to form the great vein of the limb, lying close upon the main artery. The vein on the back of the leg here joins this vein. The deep vein then continues up alongside of the femoral artery, till in the groin it passes over the share-bone, and enters the belly. The superficial vein on the inside of the leg joins it three or four inches before it enters. The two great veins of the two lower limbs now pass up to meet one another, beside where the aorta bifurcates, receive the blood from about the pelvis, and form the inferior great vein. This vein, about an inch in diameter, now passes up through the belly on the right side of the spine, and receives the veins from the kidneys, and some other small ones. Just before passing through the diaphragm, where, in a large man, it will be nearly two inches in diameter, it receives four or five large veins from the liver. The blood from the stomach, spleen, and intestines, takes a curious course. These veins meet and form a large vein which goes to the liver, where, instead of joining the great vein at once, it divides like an artery, ramifies through the liver, and then returns its blood by the four or five large veins mentioned a few lines back.

In the "Botanic Garden," that curiously imagined, and quaintly expressed poem, by Dr Darwin, there is a very pretty description of the circulation, which it may be permitted to quote:—

"So from the heart the sanguine stream distils,
O'er Beauty's radiant skin in vermil rills;
Feeds each fine nerve, each slender hair pervades,
The skin's bright snow with living purple shades,
Each dimpling cheek with warmer blushes dyes,
Laughs on the lips, and lightens in the eyes.

Erewhile absorbed, the vagrant globules swim,
From each fair feature, and proportioned limb,
Joined in one trunk, with deeper tint return
To the warm concave of the vital urn."

The principal diseases incident to veins are their becoming varicose, and their inflaming. The veins of the lower limbs, in persons who have much standing, become distended by the pressure of the long column of blood above them, so that the valves are forced ; and the pressing column thus becomes longer—and of course always the longer the worse—because the pressure is so much the greater. The blood does not now get freely back from the legs; the smaller veins become swelled and twisted, having the appearance of knots of blue cords immediately underneath the skin. Sometimes the feet become swollen and almost dropsical; sometimes the skin gives way, and bleeding ulcers form, which are exceedingly difficult to heal. To obviate these evils, the legs must be kept constantly bandaged, or elastic stockings worn, such as are to be got at the instrument-makers, to compress the limbs, and so prevent their veins from being over-distended. The inflammation of the veins occurs after their being injured, either by accident in the limbs, or by the tearing they undergo, in the womb, in the process of child-bearing. The lining membrane of the veins, when inflamed, suppurates, and pours out purulent matter, which is conveyed along with the blood through the rest of the system, producing the most disastrous effects, from which scarcely one recovers.

The forces by which the blood circulates through the veins, are generally considered to be three. The propelling power of the heart probably still exerts some influence on the blood in the minute arteries, in order to drive it into the small veins; the right side of the heart seems to exercise a suction upon the great veins which terminate in it, or at least the action of inspiration does so; and the compression of the muscles causes the blood to move towards the heart, as the valves prevent it from retreating towards the extremities. This is the reason why, in bleeding, something is generally given to the patient to turn in his hand, that the muscles of the fore-arm may be called into play, and at every motion, the stream is seen to spout with accelerated force.

When an artery is wounded, it does not heal again as a vein does; but the skin over it may heal, and then the blood is forced into the cellular tissue, forming a bag full of blood, which pulsates with great force, and is called an *aneurism.* For the cure of this disease it is necessary to expose the artery and tie it with a thread ; its sides then grow together, and the aneurism becomes obliterated, while the blood gradually finds its way through the small branches which communicate from the upper to the lower part of the limb, and become enlarged, so as to convey a supply adequate for its wants. This is one of the most successful applications of scientific surgery. Sometimes the coats of the artery dilate, and form an aneurism, without any previous wound. They are besides liable to inflammation and to ossification.

The frequency of the pulsations of the heart varies much in different individuals, but generally according to a regular gradation at different ages, becoming slower from infancy up to old age. The pulse of an infant in the womb ranges from 140 to 180 in the minute, as can be ascertained by listening with the stethoscope: after birth it diminishes in frequency, but is still above 100; in persons of adult age, from 70 to 75 is the usual average, and in men come as far as sixty, the pulse usually beats seconds. The pulse in females is quicker than in males. It varies, besides, according to various modifying causes. Exercise quickens it, rest calms it; even on sitting up, it will be found four or five beats quicker than while lying down. In some few, it may be felt beating not more than 40 in the minute. The whole quantity of blood, in the body of a full-grown man, is calculated at 35 lbs. of 12 oz., so that if the heart beats 75 times in a minute, and expels two ounces from each ventricle at each beat, the whole blood will pass through the circulation in two minutes and a-half.

THEORY AND PRACTICE OF DYEING.

CHAPTER III.

ON THE MANUFACTURE OF INDIGO—INDIGO OF COMMERCE—MODES OF ASCERTAINING ITS RELATIVE VALUES—CHEMICAL PROPERTIES—ACTION OF NITRIC ACID, CHLORINE, &c., UPON INDIGO.

In the preceding article, we mentioned that, besides the green of leaves and the colours of flowers, which we considered common to all vegetables, there were other colouring matters, which existed only in certain kinds of vegetables, and in particular parts of the vegetable. Indigo is one of these; it belongs to a genus of leguminous plants found in India, Africa, and America, named *Indigofera.* Botanists have described about sixty species of this genus. These all yield indigo; but the species from which it is usually extracted are the *I. anil*, the *I. argentea*, and the *I. tinctoria.* It is also extracted from a tree very common in Hindostan, (the *Nerium tinctorium* of botanists,) and from the woad plant, (*Isatis tinctoria,*) which is a native of Great Britain, and of other parts of Europe. The colouring matter of these plants resides wholly in the cellular tissue of the leaves, as a secretion or juice—not, however, in the blue state in which we are accustomed to see indigo, but as a white substance, which, as we shall presently see, remains white, so long as the tissue of the leaf remains perfect. When this tissue is by any means destroyed, the indigo absorbs oxygen from the atmosphere, and becomes blue.

Of the early history of indigo little is known; neither is it known when it was first used as a dye-stuff. The Greeks and Romans used it as a paint, under the name of *Indicum.* Its value, as a dye-stuff, was not known in Europe, till nearly the close of the sixteenth century, when it was imported from India by the Dutch; but our legislators, for a long time, prohibited its use in England under severe penalties. These prohibitions continued in force till the reign of Charles II., and the reason consisted in its being considered a corrosive substance, and capable of destroying the fibres of cloth, and therefore calculated to injure the character of the dyers of this country. This opinion, no doubt, sprung from the strong and interested opposition given to its use by the cultivators of the woad, which was then regarded as an important branch of national industry.

The following passage, from "Barlow's Manufactures and Machinery of Great Britain," affords a striking illustration of the political economy of the age, and of the narrow and mistaken ideas which generally prevailed throughout Europe, even down to a comparatively late era. Woad was a native production, and we need not say that all who were interested in its cultivation were zealous protectionists even in those days:—

"When indigo was first introduced, only a small quantity was added to the woad, by which the latter was much improved; more was afterwards gradually used, and, at last, the quantity became so large, that the small admixture of woad served only to revive the fermentation of the indigo. Germany thus lost a production by which farmers, merchants, carriers, and others, acquired great riches. In consequence of the sales of woad being so much injured, a prohibition was issued against the use of indigo by Saxony, in the year 1650. In the year 1652, duke Ernest the Pious caused a proposal to be made to the diet by his envoy, that indigo should be entirely banished from the empire, and that an exclusive privilege should be granted to those who died with woad. This was followed by an imperial prohibition of indigo on the 21st of April, 1654, which was enforced with the greatest severity in his dominions. The same was done in France; but, in the well-known edict of 1669, in which Colbert separated the fine from the common dyers, it was stated, that indigo should be used without woad; and in 1737 dyers were left at liberty to use indigo alone, or to employ a mixture of indigo and woad."

The plant which yields the indigo in Bengal is a small straight plant furnished with thin branches, which spreads out and forms a sort of tuft; the average height is four feet, but on good ground it sometimes attains a height of even seven feet. The leaves are soft, and somewhat like those of the common clover, and the blossoms are of a light reddish colour. The plant is at its greatest perfection when in full blossom, and yields the greatest quantity of indigo.

There are two methods for extracting the colouring matter from the leaves: the first is by fermentation and beating. This process is conducted in two large brick cisterns or vats, built in

posing the matter which gives them colour, and of which hydrogen is reckoned the basis. For the same reason, it is used successfully in destroying malaria, and putrescent miasmata, which all contain hydrogenous matter as their base, and which is seized upon by this energetic element. It is the same affinity for hydrogen which causes the evolution of oxygen gas from water which has absorbed chlorine; the chlorine combines with the hydrogen of the water forming hydrochloric acid,* and liberates the oxygen, the other element of the water.

It was stated that the grand source of chlorine is the water of the ocean. This is an enormous solution of *salt*—a universally known and indispensable article of consumption with the human race, an article indeed which seems to be essentially necessary to maintain the body in a healthy condition. Now this *salt* is a compound of chlorine and a metal; it is in fact a chloride, consisting when pure of 60 of chlorine and 40 of sodium in 100 parts; and whether it be obtained by evaporation of sea water, or be dug out of the salt mines of Wicliczka or Northwich, it has the same composition. It is never indeed found unmixed with foreign matters, but it may be separated from all impurities by appliances of chemistry, which it is not our business in the mean time to describe.

To separate the chlorine from the metallic base with which it is in combination in the salt, it is only necessary to devise a means of subverting the affinity which retains them in union. This can readily be done in the following way: introduce into a glass retort a mixture of three parts of common salt, and two parts of black oxide of manganese, and pour upon the mixture two parts of sulphuric acid diluted with its own weight of water. (A tubulated retort should be used, and the acid should be added at two or three different times to avoid too violent an effervescence.) The heat of a spirit lamp being applied to the retort, the gas will be expelled, and may be collected in bottles inverted in as little water as will answer the purpose, in order to prevent waste by absorption. This is a method of obtaining chlorine from common salt; it is that practised by the manufacturer upon an extended scale; but chlorine may be obtained more conveniently in small quantity by pouring hydrochloric acid upon black oxide of manganese in a retort, and applying a gentle heat as before. In this case, a portion of the acid is decomposed, and the element chlorine passes off in the form of a green pungent gas.

Chlorine enters into numerous highly important and interesting combinations; but we must turn from them in the meantime, to indicate the leading features of the allied elementary body

Iodine.—This element is obtained chiefly from sea-weeds, but was discovered accidentally in 1812, by M. Courtois in the mother-waters of his saltpetre works, and it has since been found in combination with potassium and sodium, in many mineral waters, such as the brine spring of Ashby-de-la-Zouch. Kelp contains it abundantly, as do also the mother-waters of the salt works upon the Mediterranean Sea; and it has been recently found in combination with silver in some ores brought from the neighbourhood of Mexico.

Iodine may be procured by drying and powdering common sea-weed—sponge for instance—and heating it with sulphuric acid; a *violet* vapour rises, which if received in a cool vessel, will condense on its sides, and form scaly crystals of a somewhat metallic lustre. These crystals are the substance in question; and it is named from the violet colour of the vapour. It is most economically procured however from the mother-water of kelp, as furnished by the soap manufacturers, who employ that crude alkali. The water is mixed with an excess of sulphuric acid in a retort, and exposed to heat, when the violet vapours of iodine distil over, and may be condensed as already described.

Iodine is always solid at atmospheric temperatures, but it slowly volatilizes, emitting a peculiar offensive penetrating odour, somewhat like chlorine. It fuses at 220°, and boils off rapidly at 350°. It enters into many combinations: two of them, the iodides of potassium and iron, are used in medicine, and another, the per-iodide of mercury, is a brilliant red pigment, but somewhat evanescent. But the chief use to which iodine has as yet been put in the arts, is the detection of a starch, with the watery solutions of which it forms a compound of a deep purplish blue colour.

Bromine.—If a large quantity of sea-water be boiled down, and the common salt removed until no more freely crystallizes, we obtain a residual liquor, which salt manufacturers call *bittern*. An abundance of it can be procured at salt-works, where it is often thrown away as useless. It contains in solution a salt of exactly analogous constitution to the chloride of sodium, but in which another non-metallic element is in combination with the sodium. It may be separated by passing chlorine gas through the liquor, which, from a superior affinity, combines with the metal, and a deep brownish yellow colour is immediately developed, and a peculiarly strong and disagreeable odour. The liquor being then heated in a retort, red vapours will pass over, and fill the receiver, and, with proper means, a few drops of a volatile liquid of a hyacinth red colour may be obtained: these are *bromine*.

At ordinary atmospheric temperatures bromine is a liquid; a little below 0° it congeals and is very brittle, and it boils at 116½°. It is poisonous. Applied to the skin it colours it deep yellow, and corrodes it. It is soluble in water, alcohol, and particularly in ether: with water it forms a crystalline combination at 32°; the crystals are octohedrons, of a red tint, and continue permanent, even at the temperature of 50°. It produces a deep orange yellow colour when mixed even in small quantities with cold solutions of starch. It combines with silver, forming with it an insoluble *bromide*, which, being in contact with organic matter, is quickly blackened by exposure to solar light. On account of this property, bromine is highly valuable in photography. Thus, if a sheet of paper be washed with a very dilute solution of the bromide of potassium, and then with a solution of nitrate of silver, the salts are decomposed, and bromide of silver is formed in the substance of the paper. The paper remains white if kept in a dark place, but is immediately blackened by exposure even to diffuse daylight. It is decidedly the most sensitive of the photographic papers.

Fluorine.—This is the name of an elementary body which has not hitherto been obtained, at least in satisfactory quantities, in a separate state. The assumption of its separate existence may therefore be considered as somewhat hypothetical, although supported by the strongest analogies. Its powers of combination are supposed to be so exalted, that no body has been found capable of subverting its affinity. Provisionally, a name has been given to it. It is met with as a component of a few minerals, but the only one of these found in abundance is *fluor* spar, otherwise called Derbyshire spar, and which, analogically, we regard as a *fluoride of calcium*—that is a compound of fluorine and calcium, the metallic base of lime.

ANATOMY AND PHYSIOLOGY.

CHAPTER XV.

RESPIRATION.—(*Continued.*)

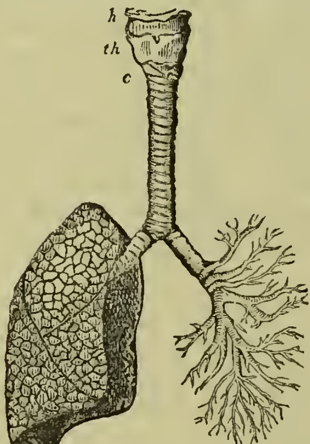
It has been already stated, that when the blood has got into the veins, and arrived at the right side of the heart, it has lost its bright red colour, and has become purple, or almost black; it has ceased to be arterial, and has become venous. The cause of this dark colour is the quantity of charcoal or carbon which it has received in its passage through the intimate

* This is, in some chemical works, still called *muriatic acid*, a name borrowed from the old one of *marine acid*, which, for popular use, was translated into *spirit of salt*. These names, as we shall see, are not inappropriate, the great source of chlorine being the salt of the ocean; but the name given in the text, and which is now very generally adopted by chemists, is better, in as far as it indicates the composition of the acid.

structure of the different organs. It has also parted with the oxygen or vital air which it held in combination. Now this black blood is calculated to produce death in two ways: first, it deprives the muscles of their power of contraction, and consequently stops the heart, which is a muscle; and secondly, it destroys entirely the action of the brain. The manner in which it produces death will be fully detailed in the article on that subject, under the head of 'Asphyxia.'

Respiration, then, is a contrivance by which the blood is brought into contact with the air, so as to permit these two fluids to effect chemical changes upon one another; and here we have to examine the structure of the lungs and the chest.

Each lung may be compared to a bunch of grapes: it consists of an infinite number of little cells, each not larger than



a millet seed, fixed upon footstalks; each footstalk being a tube, a branch of the windpipe. When the air comes in through the windpipe, then all these air-cells become filled; and this is done by the heaving of the chest, which is called *inspiration.* When again the chest falls, the air-cells are partially emptied, but never completely, and the air which was in them is blown out by the windpipe: this is called *expiration.*

The *windpipe* is a tube, consisting of eighteen or twenty cartilaginous rings, united by an elastic membrane; it is connected to the back of the mouth, where the air enters it; it passes down the front of the neck, enters the upper orifice of the chest behind the top of the breastbone, and divides into two branches, one for the right lung, and one for the left. In the lung, the windpipe subdivides into a great multitude of branches, and these into little twigs, on which the air-cells are hung—it has already been said—like grapes upon their footstalks. These tubes and air-cells are lined with a delicate membrane, called *mucous,* on account of the mucus which moistens it; and their coats become exceedingly thin, so that the air within them, and the blood without, can exercise a chemical influence on one another through them. The *pulmonary artery,* which brings the dark blood from the right side of the heart, divides into two branches, one for each lung, and each branch subdivides into minute ramifications, which spread themselves over and between the air-cells. The *pulmonary veins* take their commencement from the arterial capillaries on the surface of the cells, and unite with one another till two large ones are formed from each lung, which convey the red purified blood into the left auricle.

The vesicles have been described as being fixed to the air-tubes, in the same manner as a bunch of grapes are fixed to the footstalk; but here the similarity ends; for the cells are so small, and so close together, that no interstices between them can be perceived. Indeed, on looking at the surface of a lung, it seems to consist of an infinity of shining points, which, on being examined more closely, are found to be the cells filled with air. After air has once got into the lungs, it can never be completely expelled: hence, the lungs of a person who has breathed always float in water; and on this fact is founded the test used in criminal examinations, to distinguish a stillborn child from one that has breathed, where there is a suspicion of child-murder.

In the accompanying figure, the front of the chest is represented as cut off, so as to show the lungs without it. The windpipe is seen descending and dividing into its two branches, which are entering into the lungs; but the branches of the arteries and veins are omitted, because they would have made the small figure too complicated. Each lung is of a conical form—its base below, and its apex above—its base rests on the upper surface of the diaphragm; its apex reaches up into the root of the neck; its back touches the spine; and its front and outer parts are covered by the ribs. Towards the middle, the lungs are not in contact, being there separated

by the space in which the heart lies. Each lung is divided by fissures into lobes, of which the right lung has three, and the left only two; the place of the middle lobe being occupied by the heart, which, it has already been stated, though in the middle, encroaches upon the left side. The whole lung, except the part where the windpipe and blood-vessels enter it, is covered by a thin smooth membrane called the *pleura,* which is represented in the last figure. It is a shut sac, having one layer investing the lung, and the other lining the walls of the chest, the walls of which are in contact, so that it forms a close bag; though in the drawing, for the sake of plainness, a space is represented between them. The pleura is moistened with a thin serous fluid, similar to that in the pericardium, which enables the lung and chest to glide upon one another in the action of breathing. This membrane is very liable to become inflamed, causing acute pain, and constituting the disease called *pleurisy.* Sometimes a quantity of water is poured out into the cavity of the pleura, when the absorbent vessels do not take up what the arteries have poured out, and dropsy of the chest is the consequence. Sometimes after a chronic inflammation of the pleura, matter is formed, which presses on the lung, preventing it from performing its functions, and requiring to be let out by an incision made in the chest, between the sixth and seventh ribs.

When a child is born, its lungs are empty, and the sides of the chest are as much compressed as they can well be. Whenever it has got into the air, the elasticity of the ribs causes its chest to enlarge—the outer surface of the lung being in contact with the chest, accompanies it, and so a tendency to the formation of a vacuum is caused. The air now rushes down the windpipe, into what would otherwise be empty space, and thus the first inspiration is made, and when once made, it is repeated eighteen or twenty times per minute, during the whole course of our existence.

The vacuum produced at first by the elasticity of the ribs can never be repeated,—the lungs never become emptied of the air that now fills them, but after a forced expiration, they are at their most empty state, and they can be filled again to the utmost by an exertion of muscular power. Over each side of the chest spreads a great muscle, which may be likened to a hand with outstretched fingers, laid on the chest, the fingers pointing downward and forward—only, instead of five fingers, it has nine *indigitations.* Each of these indigitations is attached to one of the nine upper ribs, and the back part of the muscle is fixed to the posterior edge of the shoulderblade. It is not seen sufficiently well in the plate of the muscles in Vol. I. for me to refer to it. From the direction in which the ribs are curved, first outward, then downward and forward, any force acting on them from above

and behind, pulls them upward and outward, and so increases the capacity of the chest. The muscle which has just been spoken of does so constantly; but there are others which do so only occasionally, such as those which run from the chest to the bone of the arm. An asthmatic person may be seen, when the fit is on him, holding by the arms of his chair, to make them fixed points for these muscles to act from upon the chest; and he holds up his head to make these muscles of the neck co-operate in inspiration, which are attached to the collar-bone, and to the upper rib.

But the principal muscle of inspiration is one which has been spoken of already more than once, as separating the cavities of the chest and the abdomen. It forms an arched floor to the chest, having its edges attached to the ribs and to the breast-bone at the sides and in front, and to the spine behind. It is represented in the figure on the margin by the arched line *d*, as in a state of rest. It is also seen in the preceding figure arching across. When it contracts, it necessarily tends to become straighter, like the dotted line—it therefore increases the capacity of the chest; the lower parts of the lungs descend with it, while the upper parts rise with the ribs and breast-bone *b*, which comes into the position indicated by its corresponding dotted line; and thus the chest is enlarged, both upward, and outward, and downward, at once. As the diaphragm descends, it pushes the contents of the belly before it, so that, at the moment when the breath is drawn in, the belly becomes more prominent. At this time the abdominal muscles *a*, closing the belly in front and at the sides, are relaxed. When the diaphragm and elevators of the ribs cease to act, the chest falls, the abdominal muscles press the bowels up against the hollow of the diaphragm, and push it into the chest; the capacity of the chest is thus lessened in every direction, and the air which had been drawn in is again blown out, or expired.

Inspiration and expiration, then, are two different actions which are constantly going on, from the moment of birth to that of dissolution. In different persons, the frequency of respiration varies, in some being as low as 16, and in some as high as 24 in the minute. In the infant it runs as high as 40. It frequently varies with the degree of rest or activity, and with the frequency of the circulation with which it is limited, in an indissoluble sympathy. When a person is lying quiet in bed, it has already been stated that the pulse is four or five beats slower than when erect, and the respiration is slow in proportion. When again, by exercise, or even by mental emotion, the action of the heart is quickened; the breathing becomes more frequent, keeping in the ratio of 1 to 4; that is to say, that during one act of inspiration and expiration, the heart will contract four times.

Three different degrees may be observed in respiration:—First, there is the gentle equable motion which goes on when we are at rest, or when asleep, when the diaphragm and the small muscles between the ribs (see plates of muscles) are the agents which are quietly drawing in the air. Secondly, we have an increase of action when the great serrated muscles are brought in aid of the intercostals to lift the ribs, as when excited by exercise; and thirdly, we have the forced acts of inspiration, when, by a strong exertion of the will, we draw in the air to the utmost, as in asthma, or in preparation for any strong muscular exertion. The first of these is involuntary, and goes on whether we are awake or asleep; the second is also involuntary, and may be called a state of *excited* respiration. The third is the state of *forced* inspiration, when several muscles, which are not ordinarily muscles of inspiration, become so under the influence of the will.

The lungs of a man are estimated to contain about 330 cubic inches of atmospheric air, when filled as full as they can hold, by drawing in the breath to the utmost. At each act of respiration we draw in and expel about 40 cubic inches, so that when the lungs are at rest, after an ordinary expiration, they contain about 290 cubic inches. Now 40 is very nearly one-eighth of 330, so that about one eighth of the air in the lungs is renewed at each act of respiration. Besides the 40 cubic inches expelled in ordinary expiration, we can, by an act of the will, blow out 170 cubic inches in addition, making the whole quantity expired amount to 210 cubic inches. This still leaves 120 cubic inches in the lungs, which therefore never collapse, but always float in water, as mentioned near the commencement of the chapter.

From what has been stated it will at once be known how necessary it is that all houses and rooms should be so built as to contain a sufficient supply of air for the use of the inmates; that there should always be some means of renewing the air, as by the current produced by a fire in an open grate; and that, if stoves or heated air-pipes be used for distributing heat, there must be, at the same time, a set of ventilating pipes, otherwise the apartments will speedily become unwholesome, and their atmosphere incapable of supporting life. If an individual make 20 respirations in a minute, he will consume 800 cubic inches of air in that time, 48,000 in an hour, and in a day of 24 hours, the enormous quantity of 1,152,000 cubic inches. The importance of these calculations, so long neglected, is now fully admitted; and in the present day, no architect makes plans for churches, hospitals, or barracks, without calculating the height, width, and cubic contents, with reference to the breathing of the numbers that are to occupy them. Too little attention is paid to this, however, in building our ordinary bed rooms—nearly the whole space in the house is devoted to handsome public rooms, while those in which a third of our time is to be spent, are so small that the air in them is soon exhausted, and in the morning, (as is obvious to any one entering them from the open air,) they are positively unwholesome.

An account of the chemistry of respiration will be given at length in the following chapter.

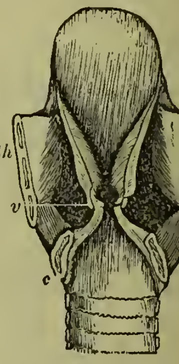
The whole of the air-passages are lined with a delicate mucous membrane, which is kept constantly moist with a thin mucous secretion. After exposure to cold, this secretion becomes increased in quantity, accumulates in the air-tubes, and excites a desire to spit it up—accomplished by coughing, which is just a short, quick, somewhat convulsive expiration. A feeling of heat is generally experienced all through the lungs from the inflammation of the membrane. This complaint generally soon goes off, by the use of warm drinks, and attention to clothing. As the inflammation subsides, the secretion becomes thicker, and is spit up in firmer dark-coloured globules. When the inflammation spreads to the substance of the lungs, the case is much more serious; the patient has a dull uneasy feeling in the lung, but not a sharp pain as in pleurisy, (which we described near the commencement of this article;) he spits up matter tinged with blood, and if the disease be not checked, such an impediment is put to the purification of the blood, that death necessarily ensues. This disease requires the most active treatment—free bleeding, several times repeated, besides the use of internal medicines, and the application of blisters, which, by exciting inflammation of the skin, cause a revulsion which lessens the inflammation of the parts within.

The most dreadful complaint to which the lungs are subject, is that which is known by the name of pulmonary consumption. In this disease the upper parts of the lungs become filled with little round grayish bodies called *tubercles*, which soon render these parts impervious to air, and so produce cough, and difficulty of breathing. After having existed in this state for some time they soften, and are spit up through the branches of the windpipe, leaving excavations of greater

or less extent. The patient, after a longer or shorter time, dies, exhausted from irritation, or, sometimes, is cut off suddenly by one of the blood vessels of the lung bursting into the cavity. Till within the last twenty years no way was known of ascertaining the existence of this sad malady, until it had gone such a length that its external signs could not be mistaken ; but now, like all the other affections of the lungs, it can be readily detected by a practised ear, with the aid of the *stethoscope,* an instrument which was already spoken of in Chapter XIII. By its aid we hear the air rushing into the air-cells, and can detect the various unnatural sounds which are the consequences of various unhealthy states of the lung. Indeed, by merely laying the ear upon the naked chest the breathing can be plainly heard. But to return ; even when we have ascertained the existence of consumption, we cannot apply the old adage, that the knowledge of a disease is half its cure ; for this intractable complaint, when once really commenced, never has been, and we may rest assured, never can be cured.

The *windpipe* separates from the gullet behind the root of the tongue, and lies in front of it in its course down the neck. Besides its principal use of admitting air to the lungs, it has another, very important too, though a secondary one, the office of producing the voice. The vocal apparatus is placed near the top of the windpipe; it is called, in anatomy, the *larynx,* from the Greek word signifying a musical pipe made of a reed, and there is no English word which corresponds to it. The larynx, besides, has two offices,—its principal one being to produce voice; and another, of no less utility, is to prevent food from getting into the windpipe in its passage from the back of the tongue into the gullet.

The framework of the larynx consists of one bone and four cartilages. The bone is not preserved in general as a part of the skeleton, for it is not united to any other bone, but is situated in the root of the tongue. It has a convex border turned forward, to which the muscles are inserted that draw the tongue forward, and protrude it from the mouth. It has two horns that pass backward, and serve like tenter-hooks to keep the bag of the gullet open at the back of the tongue. The *thyroid* or protecting cartilage is below this,—it also is convex in front, and concave behind ; it has a notch in its upper border, and is felt on the front of the neck, and seen prominent in the male, whence its common name of *pomum Adami,* as if the forbidden apple had stuck there. Below the thyroid cartilage is another called the *cricoid,* from the Greek word signifying a ring; for it completely encircles the windpipe. These parts are marked *h, th,* and *c,* in the figure of the lungs. That part of the windpipe which has been spoken of some pages back, as composed of cartilaginous rings, is attached to the lower edge of this. Placed above the cricoid, and within the thyroid, are two small conical cartilages, to which the *vocal chords* are attached. These chords are fixed in front to the hollow or indented angle of the thyroid cartilage, and are joined behind to the two conical ones, so that a slit is formed between them, which regulates the admission of air. Eleven small muscles move the several parts of the skeleton of the larynx upon one another, drawing its several parts in different directions upon one another, and opening or closing the slit or chink of the windpipe. This chink may be lengthened and widened, or lengthened and narrowed, shortened and widened, or shortened and narrowed to imperceptible degrees; thereby varying, with infinite minuteness, the musical notes which are elicited by the air passing through them. This figure represents the larynx, with a slice cut off its back part; *th* is the thyroid: *c* the cricoid; and below are three of the rings. The vocal chords *v* are seen cut across at the narrowest part. The vocal chords do not vibrate after the manner of strings, as some have supposed, who have taken great pains to prove that the larynx is at once a wind and a stringed instrument; it is purely a wind instrument, whose notes are produced in a similar way to those of the reed in a clarionet or hautboy. In the clarionet, the reed is always the same, and the different notes are produced by lengthening or shortening the sounding tube, by stopping or opening the holes with the fingers. In the larynx, the reed is continually being changed by the variations in the vocal chords, while the length of the pipe is also varied by the elevation and depression of the larynx, through the means of the muscles which attach it to the chin above, and to the breast-bone beneath. This motion is easily felt, if the finger be laid on the fore part of the neck while singing: in running up the scale, the projecting cartilage is felt rising a step for every note; and, towards the top, additional elevating power is gained by holding up the head, and pushing out the chin.



The chink between the vocal chords is not, at the utmost, more than three quarters of an inch in length, and varies in width from a quarter of an inch to absolute closure. Hence it must be obvious, that a small substance getting in will block it up altogether, and that thickening of the chords from inflammation may narrow it so much as to produce death by suffocation. This is what takes place in fatal cases of croup : layers of a firm whitish substance, of the consistence of boiled white of egg, are formed in the interior of the windpipe, which narrow it, and prevent the free ingress of air ; and, if relief be not obtained from the most active medical treatment, death will speedily ensue. The narrowing of the chink gives rise to the convulsive cough, and the peculiar ringing sound of the respiration, which are characteristic of the disease.

As soon as food reaches the back of the throat, it passes from the power of the voluntary to that of the involuntary muscles, and is conveyed into the stomach by a regular wave-like action of the muscular gullet or œsophagus. When persons eat too fast, and one morsel is passed into the throat too quickly after the other, this regular muscular action becomes spasmodic, producing a very painful sensation.

Where foreign bodies get *into* the windpipe, their presence there is a proof that they cannot produce death by suffocation ; because the chink is the narrowest part of the tube, and they have passed that. They are, however, driven up and down by the successive currents of air, and produce much irritation, and at length death from inflammation of the lungs, if not extracted. The operation for removing them is a very simple one ; an incision is made on the front of the neck down to the windpipe, which is then slit up for near an inch. No poking with instruments is required, for the moment the opening is made, the foreign body is blown out with great force. A cherry or plum stone is the substance which, in most cases, has got into this awkward situation.

In order to prevent food or drink from passing into the windpipe while being swallowed, a valve is placed over the orifice of the larynx. This valve is called the *epiglottis.* It is shaped like an obovate leaf, fixed by its footstalk to the inside of the angle of the thyroid cartilage, while its broader part can be laid down over the orifice so as completely to close it. It stands erect in its natural position ; it has no muscle to pull it down, but is pushed down mechanically by the ball of food which passes over it from the root of the tongue to get into the gullet, and the moment this has passed it again rises by its elasticity. Indeed, food can never get into the windpipe but when this part is taken by surprise, either by speaking or laughing while swallowing, or by swallowing in a hurry as a child does when in fear of detection in having stolen some sweet thing.

The only complaints about the larynx, occurring in adults, are an affection somewhat resembling the croup of children, and an ulceration in the inside, reaching even to the cartilages, which is occasionally found in persons perishing from consumption.

the pile: it goes far towards explaining what is generally called the intensity of current electricity, as well as why it is, that a pile, which produces powerful physical effects, may be extremely ineffective in the production of chemical or physiological effects, and reciprocally.

95. Adopting this mode of measurement, M. Pouillet has made some important experiments, and drawn some highly valuable conclusions, which it would not be proper to pass over. The voltaic instruments employed by him were the constant piles discovered by M. Becquerel in 1829, in which he employed two metals, and two fluids separated by a diaphragm. The intensities of the currents were measured by two different instruments, one called the *compass of tangents*, the other the *compass of sines;* and for very feeble currents, these compasses had a multiplier instead of a simple circuit.

96. In order to ascertain the different degrees of diminution, which the intensity of a current, developed by a single pair, suffers, when it traverses circuits of different lengths, pieces of wire of copper, platinum, silver, iron, &c., covered with silk, and proceeding each from a similar piece of metal, were drawn out with such care that the diameter of each wire was sensibly the same through the entire of its length; from each piece were cut five smaller ones of different lengths, and with each series the following experiments were made:— The current produced by the voltaic pair was made to traverse the compass directly, and the deviation was observed; it was afterwards made to traverse in succession each of the five wires, the corresponding deviation being carefully noted.

97. Many experiments made with the series described, as well as various others made with wires of different kinds, having led to the same result, Pouillet derived from them the following general law:—"The intensity of the current produced by a single pair, is in an inverse proportion to the real length of the circuit." Some analogous experiments have demonstrated that the resistance of the single pair, or the primitive length of the circuit, is expressed by lengths which are proportional to the section, and to the conductibility of the wire which composes the apparent length of the circuit.

98. Inasmuch as the intensity of the current measured by the apparatus is in an inverse proportion to the real length of the circuit, we may draw this important conclusion, that the current produced by a single elementary pair, is capable of a constant electro-dynamic effect; for the influence that is remarked on the magnetised needle, arises only from a certain fraction of the real length of the circuit. But if that influence be increased tenfold—say the real length of the circuit—this fraction becomes ten times as small, and, at the same time, we obtain only one-tenth of the intensity; it is, therefore, clear, that in the two cases, we should obtain equal degrees of intensity, if it were possible, under similar conditions, to cause the total length of the circuits to act on the needle.

99. This must be considered quite a fundamental principle in theory, inasmuch as it demonstrates that the peculiar agency which constitutes the current, may be assimilated to a quantity of motion which must continue constant whatever may be the extent of the mass through which it is transmitted. Thus, if the two poles of a voltaic pair be connected by a wire of one inch, or by one of one thousand inches, neither more nor less electricity passes in the one case than in the other—the quantity that does pass, remains always constant, and depends altogether for its supply on the combination itself, or upon the electric source, whatever it may be.

100. When two points of a circuit, traversed by any current, are touched by the extremities of a metallic wire, the current must be divided at those points—one portion continuing to pass along the circuit as before, and the other taking the direction of the wire. This second portion may be called "derived current;" that portion which passes between the points of derivation, "partial current;" the undivided current, which passes before and after the points of derivation, may be designated "principal current;" and the current transmitted before any derivation was made, "original current."

101. The following general laws have been deduced from the results of experiments upon the intensities of the derived, partial, and principal current:—

1st, Upon a derivation being made, the intensity of the original current is increased; thus, the principal current is always stronger than the original.

2d, The intensity of the derived current is proportional to the distance of the points of derivation.

3d, At an equal distance, the intensity is in an inverse proportion to the section, and conductibility of that portion of the circuit in which the derivation is made.

4th, The sum of the intensities of the partial and derived currents is always equal to the intensity of the principal current.

102. It has been further shown that the principles demonstrated for one elementary pair, apply with equal force to a pile composed of any number of pairs; and it has also been ascertained, upon placing several elementary pairs pole to pole, and thus forming a pile with great surface, and a single element, and connecting the two positive and two negative poles of two such elementary combinations, whose individual intensities had been previously ascertained, that, in each case, the individual currents of the two elementary combinations join and superpose themselves in some way, without any particular modification. This result is important, for it shows that when a wire is traversed by a current of a certain tension, it is not less fitted for the transmission of another current, even though originating from a source of less intensity, which may be taken to afford fresh proof, that the currents are assimilated to certain quantities of motion, and that it is not requisite to consider electric conductors as a species of tube affording passage to a fluid, and presenting an increased resistance in proportion to their increase of length, so that the fluid diminishes in velocity or quantity, and is forced either to reflow toward its source, or, at all events, to be accumulated in a greater proportion.

103. A general view of the experiments referred to in the preceding sections, leads to the two following laws, which are of singular simplicity:—

1st, An electric source is capable of a constant electro-dynamic effect, whatever may be the length, section, and conductibility of the metallic circuit that its current has to traverse.

2d, When several electric sources are connected, their currents join, or superpose themselves without modification.

104. The results of experiments, already very numerous, appear to warrant the conclusion, that an electric source is capable of developing a constant quantity of heat; and that it is possible to calculate by quantities of heat, or of ice melted, the quantities of electricity evolved by voltaic combinations, or other electric sources.

ANATOMY AND PHYSIOLOGY.

CHAPTER XVI.

LIEBIG'S THEORY OF RESPIRATION.

In the article on "the circulation," it was explained, that in the higher classes of animals, the blood was sent through lungs, so as to be exposed to the air, in the intervals between the times in which it was circulated over the body. It was also shown how the heart, and arteries, and veins were modified, in various ways, in order to bring the blood conveniently in contact with the atmosphere. In the last article (p. 551) the quantity of air used was stated; and it was pointed out, of how much importance it is, in building halls or dormitories, to calculate their size, so that their cubic contents may correspond with the respiratory necessities of those who are to occupy them.

It has been ascertained by chemical calculation, founded on careful experiments, that nearly eleven ounces of charcoal are expelled from the lungs in the four-and-twenty hours; so that, in this respect, the windpipe may, not inaptly, be compared to a chimney. We shall see, immediately, that this comparison holds good in another point of view, for the lungs, seen in this light, are extremely like a couple of furnaces. It was long supposed, that the purifying of the blood, by getting quit of its carbon, was all that was necessary—that this was the *end* of the function of respiration. *Now*, on the other hand, there are strong grounds for thinking that this getting quit of the carbon is but a *means* toward an end—that the carbon in combining with the oxygen of the air, is actually *burned*, and that this combustion is the cause of animal heat. It has long been known that heat was in some way the result of breathing, but to explain exactly how, was the difficulty. It has been left, for a chemist of our own day, to set this subject clearly before us—as clearly, perhaps, as it can possibly be. Liebig, the professor of chemistry at Giessen, in Germany, lately published a most admirable book, which has been clothed in an English dress by Dr. Gregory of Aberdeen, who was well known in Glasgow before his removal thither some years ago. The book is entitled, "Organic Chemistry, applied to Physiology and Pathology." A correct abstract of the doctrines of the distinguished author ought to be acceptable in this place, although the writer of these papers cannot, of course, pledge himself for their accuracy in a philosophical point of view.

"Hitherto," says Professor Liebig, "in attempting to investigate the theory of those *vital motions*, which we call the *actions* going on in the intimate structure of animal bodies, only one condition was possessed—namely, a knowledge of the apparatus. The exact nature of the substance of the organs themselves—the changes which they produce upon the food—its transformation into the substance of organs—and afterwards, its transformation again into lifeless or inorganic compounds—also, the share which the atmosphere has in aiding these changes—all these foundations for future conclusions were awanting."

All the parts of the animal frame are formed out of a peculiar fluid, which circulates through every cell of every organ. All the parts consisted originally of blood, or, at least, had been made of materials which were brought to the growing organs by means of this fluid. Experience further shows us, that at every moment there is a change taking place; that a part of the structure is losing its life, becoming transformed into unorganized matter, and requiring to be renewed, and to have its place supplied. Besides, every motion, every manifestation of power, must be the result of a transformation of structure or of substance. In order to keep up the phenomena of *life*, then, there must be *nourishment*. Some part of this is wanted for the increase of the mass, some part is needed for repairing loss, and some part is expended in producing force.

If, then, the *first* condition, necessary for the maintenance of life, be a due supply of nourishment, the *second*, of no less importance, is the *absorption of oxygen from the atmosphere*. Viewed as an object of scientific research, animal life exhibits itself in a series of phenomena, consisting of the *changes* which the food and the oxygen which have been taken in undergo *in the body*, under the influence of *life*, or what has been called *vital force*. We say, under the influence of life, because, though all the parts remain the same, these changes do not go on in the dead body.

During life, there are constantly two changes going on; there is new matter moving in, and *passing to* a state of rest; and there is old matter, which *has been* at rest, passing into a state of motion; in two words, there are the processes of *addition* and *decomposition*. In vegetables, we do not see this double change, but only the first; we see new matter passing into a state of rest, and adding to their size and growth, but we see no waste. In animals, there is both growth and waste.

The matter taken in consists of food and oxygen. Food is taken at certain times; oxygen is taken continually, without ceasing. Yet, accurate experiments have shown, that a man, supplied with a sufficiency of food, and breathing regularly, neither becomes heavier nor lighter in the twenty-four hours, and yet the quantity of food and of oxygen taken in must have been very considerable. In a year, a man takes in 746 lbs. of oxygen, yet his weight remains the same, or has varied but a few pounds. What, then, has become of it? The question can be answered satisfactorily,—no part of it has remained; it has all been given out again, in the form of compounds, with carbon and hydrogen. The carbon and hydrogen of certain parts of the body have entered into combination with the oxygen of the atmosphere, through the lungs and skin, and have passed off under the forms of carbonic acid gas, and the vapour of water. At every moment, at every expiration, certain quantities of these elements separate from the body, having combined, within it, with the oxygen of the atmosphere.

Suppose that a man has 24 lbs. of blood within his body, (a very small quantity, but it will serve for the basis of a calculation,) from its known chemical composition, in order to convert the whole of its carbon and hydrogen into carbonic acid and water, 64,103 grains of oxygen will be required, which quantity will be taken in at the usual rate of breathing in four days and five hours.

It is quite plain, that whether the air combine directly with the blood, or with other parts of the body, which it carries away, so as to form carbonic acid—the body of a man, which takes in daily 32½ ounces of oxygen, must daily receive as much carbon and hydrogen, from without, as will supply the blood anew with these elements, to supply the place of the old quantity which has been parted with, in order to combine with the air. Further, since no part of the oxygen taken in by breathing is again given off, except as a compound of carbon or hydrogen; and since the carbon and hydrogen given off are replaced by carbon and hydrogen in the food, it is clear that the amount of nourishment required by an animal which breathes air must be directly proportionate to the oxygen which is taken into the system.

Two animals, which, in equal times, take up by means of the lungs and skin, unequal quantities of oxygen, consume unequal quantities of nourishment. Then, the quantity of oxygen taken up depends on the *number* of the respirations; hence, the quantity of nourishment will vary according to the number and force of the respirations. A child, in whom the respiratory function is very active, requires food oftener than an adult, and bears hunger less easily. A bird, whose consumption of oxygen is so great that its blood is three or four degrees hotter than a quadruped's, dies on the third day that it passes without food; while a serpent, whose respiration is very sluggish, will live without eating, for three months, or more. Again, the number of respirations is smaller when we are at rest, than when at active employment, so that the quantity of food required will vary on this account also. An excess of food, then, without exercise, and the increased frequency of respiration, and increased consumption of oxygen, which are necessary accompaniments, is bad for the health; and so, also, is the opposite, increase of exercise, or excessive labour, without a sufficient supply of food. In either case, the constitution suffers.

Again, the chemist shows us that air expands by heat, and becomes denser under the influence of cold. The *bulk* of the air used in respiration continues the same, but its *weight* varies. Besides, in summer, the air contains a proportion of watery vapour, in consequence of the evaporation which the heat is occasioning; while in winter it is dry, in so far as this source of moisture is concerned. Hence, the space which in summer was occupied by vapour, is in winter occupied by air itself; and that air, from its density, contains more oxygen.

It is clear, then, that since in winter, we draw in more *oxygen*, during respiration, than in summer, we must also send out more. But we send it out as *carbonic acid*, in consequence of the combination with it of the *carbon* which ha

been brought to the lungs in the venous blood, after having been collected in the course of the circulation. More carbon then is given off in winter than in summer; that is to say, there is more *waste* constantly going on. Hence arises the necessity for more food in winter than in summer—a feeling of which every one is conscious, though he does not know its cause. In warm climates, for the same reason, the food taken in is less nourishing in its quality, as well as less in quantity—the people live on fruits and grain, while, in the far north, they luxuriate on fat bacon and train oil. It is no difficult matter to be moderate in warm climates—want of food can be borne for a long time under the equator; but cold and hunger united, soon exhaust the strongest body.

Another very interesting branch of this subject next comes before us, namely, that the mutual action of the food and oxygen in the body, is the *source of animal heat.*

All living creatures, depending for existence on the breathing of oxygen, have a source of heat within themselves, independent of surrounding objects. This statement holds true of all animals, and its application extends to the springing of seeds, the flowering of plants, and the ripening of fruits. Only those parts to which the oxygen goes, possess heat. Those parts which have no circulation, as hair, wool, and feathers, have no heat in themselves; they aid in keeping a creature warm, because they neither radiate nor conduct heat. The temperature of animals, therefore, is the result of the combination of carbon with oxygen. This combination, chemists well know, *cannot* take place *without heat;* and whether it be evolved so rapidly or so slowly, as to produce a high or a low temperature, still, the absolute quantity of heat is the same.

Every one, who has attended the most popular chemical lecture, has seen a bit of charcoal burnt with great splendour in a jar of oxygen. Now, the carbon of the food, converted into carbonic acid in the body, gives out as much heat as if it had been burnt. In pure oxygen, the heat is intense, because the combustion is rapid; in common air it is less intense, because slower; within the body, it is more gradual still.

From all that has been said, it must be plain, that the heat of the body will be greater or less, according to the greater or less quantity of oxygen used in respiration. The more frequent the respirations, the greater will be the heat. An infant, who breathes thirty times in the minute, maintains a temperature of 102°, while an adult, who breathes eighteen times, will show a heat of only 98°. Birds maintain a temperature of 104° or 105°; quadrupeds from 98° to 100°; and even fishes and amphibia, are 2° or 3° warmer than the water in which they live. All animals, therefore, are strictly *warm-blooded, i. e.*, warmer than the medium in which they live, though only so warm as to deserve the name, in those who breath by means of lungs. The most trustworthy observations on the temperature of man and the lower animals, show that it remains the same in all climates, being regulated by several different circumstances.—(See Vol. I. p. 202.)

The animal body is a heated mass, bearing the same relation to the surrounding objects, as any other heated mass, which receives heat, or loses heat, from the other bodies round it. Its rapidity of cooling will vary as the external temperature varies; yet the lost heat is made up, and the temperature is kept equable.

It is evident, then, that the heat lost by cooling is supplied by the mutual action of the elements of the food and the inspired oxygen, which combine together. The animal body is a furnace, of which the food is the fuel. It matters not what forms the food assumes, nor what changes it undergoes within the body—the *last* change is always the same; carbon is converted into carbonic acid, and hydrogen into water, each by the addition of oxygen; while the unburned carbon, and the nitrogen, whether from the unused food, or from the old parts of the body which have been absorbed, are expelled as urine and perspiration, or as solid excrement. Of course, in order to keep the furnace at a constant temperature, we must vary the supply of fuel according to the temperature of the surrounding air, as that regulates the supply of oxygen, by altering its density.

From what has been said, it must be plain, that in winter, when we take active exercise in the cold air, and the amount of oxygen which is inspired, increases, our need for food containing carbon and hydrogen increases in the same ratio; and it is a wise provision of our Creator, that, by gratifying the appetite which has been thus excited, we obtain the most sufficient protection against the most piercing cold. A starving man is soon frozen, as we should expect from this rule, and the beasts of prey in the arctic regions greatly exceed in voracity those of the torrid zone.

In the temperate and frigid zones, the denser air which is respired consumes the body so much faster, that it urges men to labour, to furnish the means of subsistence; while in hot climates, the waste being much less, the necessity of labouring for food is much less urgent. Hence, the natives are reckoned lazy; and those, whose state of slavery deprives them of the power to choose, are compelled by the lash to labour for others whose station in life enables them to comply with the requirement of the climate by living at ease. Our clothing, in this point of view, is merely an equivalent for food. The more warmly we are clothed, the less urgent is the need for food, because the loss of heat by the cooling of the surface, and the necessity for supplying it again by food, are lessened too. If we ran about naked, like savages, hunting and fishing, we should be able, during the cold of winter, to eat, like the Samoiedes, eight or ten pounds of flesh at a sitting, and finish with a dessert consisting of a dozen of tallow candles! The spirits and the train oil which these northern savages swallow in such profusion, consist of combustibles, carbon and hydrogen, and only suffice to keep up the equilibrium between the external temperature, and that of their own bodies.

Let us now look at this subject in relation to health. The Italian cannot take more carbon and hydrogen in his food than he expires under the form of carbonic acid and water; and the Laplander cannot expire more carbonic acid and water than he takes in as food, unless in starvation, or while labouring under disease. The Englishman in Jamaica regrets the disappearance of his appetite, which had previously been to him a source of constantly recurring enjoyment, and he succeeds, by means of pepper and other stimulants, in getting himself to swallow as much food as he was accustomed to do at home. But *the whole of the carbon is not consumed;* the oppressive heat prevents him from increasing the number of respirations by active exercise, and so proportioning the waste to the amount of food taken; the carbon, therefore, accumulates in the system, and disease is the inevitable consequence.

On the other hand, England sends her sick, whose deranged digestive organs have lost the power of bringing the food into a fit state for combining with oxygen, and therefore are, *in their own persons*, ready to be consumed by it, to southern regions, where, from the heat, the amount of oxygen inspired is diminished in so great a proportion; and an obvious improvement in health is the result. The weak organs of digestion have power enough to digest food enough to combine with the smaller quantity of heated oxygen which is inspired; while, in a colder climate, this necessary amount of digestion being impossible, *the organs of respiration, the lungs themselves*, would have become the fuel to the flame In our own climate, bilious diseases, or those from excess of carbon, are prevalent in summer, while pulmonary diseases, or those from excess of oxygen, prevail in winter.

The cooling of the body, it has been already explained, increases the amount of food necessary, and so is an important agent on the health of the digestive organs. Mere exposure to the air, even without exercise, in a carriage or a boat, by increasing radiation and vaporization from the surface, increases the loss of heat, and compels us to eat more than usual. The same is true of those who take large draughts of cold water, which is given off again in perspiration, or urine, at the temperature of the body, 98°. This process increases

the appetite, to restore the carbon, and renders exercise necessary to quicken the breathing, so that oxygen may be supplied, in order to restore by combustion, the heat which had been carried off by the vaporization of the cold water. For this reason, long continued speaking, the crying of infants, and the dryness of the air, all exert a decided influence on the quantity of food taken.

The effect of the process of respiration is clearly seen, if we watch the state of a man or other animal, totally deprived of food. The first effect of starvation is the complete disappearance of the fat; and this fat cannot be traced into either the urine or the excrement. Its carbon and hydrogen have been given off by the lungs, in combination with oxygen, and have obviously served to support respiration. In the case of a starving man, 32½ ounces of oxygen enter his body daily by the lungs, and pass out again, in combination with carbon and hydrogen, of which there will be about eleven ounces of the former. An individual, who was unable to swallow, lost 100 lbs. of his weight in a month; and a fat pig, which was overwhelmed by a slip of earth, and was dug out after passing 160 days without food, had lost 120 lbs. The way in which the hybernating animals waste during the winter, and the periodical fattening of many animals in the autumn, and their getting leaner during the winter, are additional proof that the oxygen consumes whatsoever is capable of entering into combination with it. As starvation goes on, the fat having been exhausted, the muscles shrink, and the brain becomes partially absorbed; hence delirium and ravings occur before death closes the scene. In all chronic or long-continued diseases, death is at length produced in the same way, chiefly from the wasting occasioned by the chemical influence of the atmosphere.

GEOLOGY.

CHAPTER XIV.

FOSSIL PLANTS OF THE COAL FORMATION.

When led to admit the vegetable origin of coal, we naturally direct our attention to the character of the plants from which it was produced; and here a field of inquiry opens on our view, replete with interest, whether we contemplate it with the eye of the botanist, or the scrutiny of the philosopher. In the fossil plants of the carboniferous rocks, we find genera, and even families which have been long lost in the scale of vegetable creation, but so connected with the existing order of Nature, as to fill up the links which seemed wanting to complete the harmony of creation; and in others we are able to trace analogies of structure and form, that forcibly convey to our minds the impression, that from the time our infant planet began to be adorned with the beauties of the vegetable kingdom—though its floral riches, the garniture of blossom, or the luxury of fruit, were not conspicuously developed,—yet the plants of that most remote epoch must have displayed a symmetry of structure, and gorgeousness of appearance, not surpassed, if even equalled, by the tropical forests of the present day.

The generality of the stems of plants found in the coal formation are commonly so much compressed, as to warrant the conclusion that they were hollow or succulent. As already noticed, they occur in the sandstones, clays, shales, and half-formed coal. The best impressions are found in the shales, or slaty clays; on the surface of which the most delicate markings are preserved of the nerves of the leaves, and the dottings and striations of the stems. In many instances, the bark is converted into coal; while the central portion of the stem consists of the same material as the bed in which the plants occur. In other instances, instead of the sandstone or shale which forms the matrix, the mass is converted into carbonate of iron, sometimes crystalline, or a calcareo-silicious compound.

The roofs of some of the coal-beds exhibit great beauty of appearance, and a vast profusion of plants. The most remarkable that has come under our personal observation is that of the splint-coal at Monkland Iron Works, near Airdrie. It answers very much to the following magnificent description of a similar deposit, by the Rev. Dr. Buckland:—"The finest example," says he, "I ever witnessed, is that of the coal mines of Bohemia. The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces, bear no comparison with the beauteous profusion of external vegetable forms with which the galleries of these instructive mines are overhung The roof is covered with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage, hung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the black colour of these vegetables with the light ground of the rock to which they are attached. The spectator feels himself transported, as if by enchantment, into the forests of another world: he beholds trees of forms and characters now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, all spread before him, little impaired by the lapse of countless ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians."

The plants, which occur in the manner so beautifully described by the Doctor, are generally not in direct contact with the coal-bed, but at a little distance above it. The fern fronds and other leaves are separated from their stems, and frequently lie in the most confused manner, intermingled with long stems of stigmaria, denuded of their leaves—gigantic calamites—and the long sedge-like leaves of the flabellaria, a plant allied to the gramineæ, or the palms. As far as our observation has gone, stems of Sigillaria, and Lepidodendra, are rare in such situations. The leaves of most common occurrence are those of ferns. Fruits, apparently those of palm trees, sometimes occur. It is perhaps worthy of remark, that the shales in which commingled collections of fossil vegetables are met with, generally contain perfect casts of bivalved shells (unios?), and the remains of fishes—a circumstance which tends to show that, whether the plants constituting the coal-beds grew on the spot or not, the vegetable remains imbedded in the superincumbent shales were drifted from a distance.

A very ingenious plan has lately been devised for ascertaining the true character of fossil plants, by cutting the coal, or other substances into which they have been converted, into thin transparent slices. Geologists had hitherto only attempted to classify fossil plants by the peculiarities of their external appearance. This, however, was very unsatisfactory, because the external markings are frequently defaced, and the bark converted into coal, in which little or nothing of the outward character of the plant is preserved. By cutting the specimens, however, into thin slices, and subjecting these to the microscope, or even, when sufficiently transparent, to the naked eye, we are able to trace the minute cells and vessels of the original vegetable texture, with an accuracy and distinctness equal to that by which we become acquainted with the structure of living species. It was by means of this kind that Mr Nicol of Edinburgh was enabled to ascertain the coniferous character of the celebrated trees found in Craigleith quarry, near Edinburgh, about twenty years ago; and to determine them to have belonged, not to the common fir, but to the Araucaria, a genius of pine now only found in Norfolk Island, South America, and New Holland.

In order to accommodate such of our readers as may not be acquainted with the physiology of the vegetable kingdom, it may be useful to notice briefly a few of the leading phenomena connected therewith, before entering upon a description of the coal plants.

The matter of which the various parts of vegetables are composed consists of two substances, denominated vascular and cellular tissue. Those plants which, like the fungi or mushroom tribe, consist exclusively of cellular tissue, are

die away;—as the carrot, the cabbage, the foxglove. Perennial plants are those which live many successive seasons. Some of them are herbaceous, sending up stems and leaves, which flourish and fade down to the ground in one season, as the asparagus does; while the root remains, and sends up a new crop with the returning spring. Others remain entirely above ground, and aro called shrubs or trees. In the botanical books, certain signs are used for these modifications;—⊙ signifying annual; ♂, biennial; ♃, perennial. Plants are sometimes changed from annual to biennial and perennial, by change of climate and cultivation.

It is only necessary farther to remark, that it is improper to perform transplantation except when the juices of the plant have retired, and it is dry, as during winter; and then the new radicles shoot out again in spring, just as if the plant had been left alone.

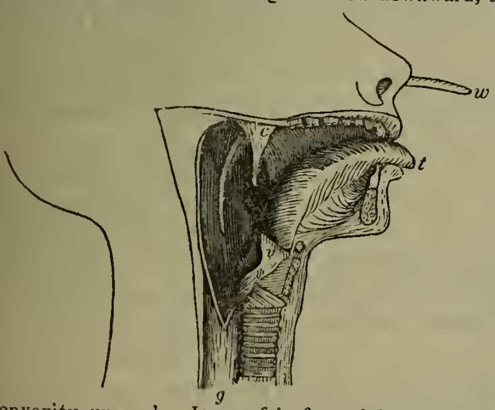
ANATOMY AND PHYSIOLOGY.

CHAPTER XVII.

OF DIGESTION.—THE MOUTH AND TEETH.

In all living bodies there is a continual waste going on which requires to be repaired by nourishing matter taken from without, and added to the system. Vegetables depend for their existence on extraneous matter, which is taken up by the roots, and distributed by means of the sap-vessels. But the grand characteristic of animals is their possessing a stomach, a central cavity into which the nourishing matter is first put, to be thence taken up into the circulation, and so distributed all over the system. The stomach and bowels constitute the proper digestive apparatus, and several other organs which co-operate in various ways to aid it, are the assistant digestive apparatus. Besides, we have a set of organs for preparing the food for the stomach, tearing, bruising, and grinding it, and mixing it with fluid, that it may be easily swallowed and digested. It is most convenient, though, perhaps, not most philosophical, to trace these parts successively from the mouth downward; we will therefore commence with the jaws, mouth, and teeth; examine the salivary glands, the palate, and the bag of the gullet; inquire into the nature of the action of swallowing, and trace the food as far as the stomach. From the stomach we will follow it down into the small intestines; see how it is mingled with the bile and the pancreatic juice; and learn how the nourishing parts of it are absorbed and carried into the circulating mass; and how that part which is useless is pushed on, until it be expelled from the body.

The *mouth* is a cavity having somewhat the shape of a hemisphere, the flat surface being directed downward, and



the convexity upward. Its roof is formed by bone; it is shut in at the sides and front by the muscular parts forming the cheeks and lips; below, it is enclosed by the lower jaw, and its floor is formed by the tongue. In the figure, the right half of the lower jaw has been removed, leaving the bag of the *pharynx* open. From the back part of the mouth hangs down the *pharynx*, a conical bag, which leads into the gullet *g*, and the nose communicates with it from above, as shown by a piece of whalebone *w*. Hence is the reason that we can breathe equally by the nose or mouth; and, that sometimes if we be taken by surprise with a fit of coughing while swallowing, the contents of the throat run out through the nose. In order to prevent this from occurring constantly, there is a curtain *c* placed at the back of the mouth, which we see on looking into a glass; and which rises or falls according to the necessity for its being applied either above or below. A long red tassel hangs down from the centre of it, nearly touching the top of the tongue, endowed with great sensibility, and warns the curtain to rise whenever the food comes in contact with it. When food is about to be swallowed, it is rolled about in the mouth and mixed with saliva, till it forms a kind of ball; and when this gets to the back of the mouth, between the arches of the palate, there is felt an irresistible tendency to swallow. The curtain now rises so as to prevent any of it passing up into the nose; the tongue rises against the roof of the mouth, so as to keep it from getting forward again; and the only course left for it is to pass down into the gullet, pushing down the valve *v* of the windpipe as it passes. It is a mistake, however, to suppose that food *falls* into the stomach, the fact being that a man can swallow nearly as well when standing on his head as on his feet. This will be understood if we suppose an imaginary division of the gullet into a number of rings. When one ring contracts, the food passes on into the next; then the second contracts, and squeezes it down into the third; while the first being still contracted, prevents it from getting up; and so the process goes on, regularly downward, until the ball arrives at the stomach. And in vomiting, an action precisely the reverse of this takes place, and the food is *squeezed up* from the stomach into the mouth, although so rapidly that its passage seems almost instantaneous.

The *tongue* is fixed to the back of the chin, and has a muscle arising from this point, and radiating through it, forward, upward, and backward; so that it can protrude the tongue, turn it upward, downward, or to the side, render its surface convex or hollow, to serve for a conduit, as in drinking. There are three pairs of muscles actually forming the substance of the tongue, and not less than six pairs more which can aid in its motions. The whole inner surface of the mouth is lined with a soft mucous membrane, so called because it pours out a mucus from its surface to lubricate it, to protect it, and to assist the food to slide easily through it. The upper surface of the tongue is studded with many delicate *papillæ* or points, in which the nerves of taste end, which vary in appearance in different animals. In the cow, for example, they are much rougher than in man; in the lion they are so rough as to be capable of peeling one's skin off, should he attempt to lick it; and in some of the marine animals which swallow living shell-fish, both the tongue and the gullet are covered with thickly set spines, directed backward, to prevent their prey from actually creeping up again.

Six *glands* are placed about the mouth for the purpose of supplying *saliva* to be mixed with the food. Two very large ones lie behind the ear, in the hollow between the lower jaw and the temporal bone, so that the motion of eating squeezes out their contents. Their *ducts* run forward in the cheek, and perforate the mouth opposite the second last tooth in the upper jaw, where, with the tongue, a small soft projection may be recognised. Two others lie on each side under the tongue, having a common duct, which may be seen opening on the fold of the membrane that bridles down the tongue. This fold, by the by, it may be mentioned here, is what produces the appearance called *tongue-tacked* when too short. The tongue cannot then be put out of the mouth, and the infant cannot suck until the fold be divided by a pair of scissors. This little operation, trifling though it be, should never be intrusted to any one but the attending surgeon; for there are a couple of arteries lying close to this bridle, which are apt to be divided by an ill-directed incision. The tonsil is

seen in the last figure, just beyond the little tassel; it is of the size and shape of an almond, secreting mucus to moisten the throat from many little pits on its surface. It is this which inflames, when one is said to have a sore throat. Sometimes it enlarges so much as to interfere with breathing; and then it requires to be removed.

One or other of the ducts which open below the tongue is subject to become stopped up, and the saliva distends it into a soft swelling, which impedes the motions of the tongue in the actions of speech and mastication, and requires to be punctured. Sometimes the saline constituents of the saliva concrete into a stone, which requires to be cut out. But the most annoying thing connected with the salivary duct is, when one of those running in the cheek is divided, as by a sabre cut; it is then scarcely to be got to heal, and the saliva is constantly running over the cheek. The quantity which is lost in this way, in such a case, in the course of a day, is surprisingly great.

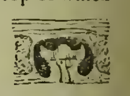
The *teeth* are the hardest parts of the whole body. In the adult they are thirty-two in number, eight upon each side of each jaw. They are of four different kinds. In front there are, on each side, two incisors or cutting teeth, whose edges are like that of a chisel; next there is one eye-tooth, which is pointed; thirdly, there are two small grinders; and lastly, there are three large grinders. The teeth in the two jaws do not exactly meet; the cutting teeth of the upper jaw overlapping those of the under, while the grinders just face one another. We sometimes, however, see people whose under teeth project beyond their upper, giving a peculiar appearance of length to the lower part of the face.

In the figure a grinding tooth is represented, sawn through perpendicularly. We describe three portions of the tooth, the *crown* being that part which appears above the gum, the *body* the thick part, and the *fangs*, or roots, penetrating down into the socket. A cavity is seen in the body of the tooth, occupied by a pulpy substance, containing some bloodvessels and nerves; and a small canal is seen leading from the cavity into each fang, and opening by a minute hole, through which the bloodvessels and nerves enter.

The bony part of the tooth which projects above the jaw, and is destined to meet its fellow, and to come in contact with the fluids in the mouth, is protected by the *enamel*, which is the hardest substance in the body. It is thought not to be an organized substance at all, as neither blood nor sensibility has been detected in it; so that it seems to be merely a protection, to prevent the remainder of the tooth from being worn. When broken off, it is never replaced, and the tooth of necessity passes into decay.

The structure of the bony part of the tooth is similar to that of bone elsewhere, only it is much harder. Hence, by referring to the chemical structure of bone, (Chapter IV.,) it will be understood how the teeth are pained when anything sour is taken into the mouth; why the patient who is to use acid drops is always directed to suck them through a quill, that they may not come in contact with the teeth; and how the teeth blacken, and are actually dissolved away, in persons who are subject to acidity of the stomach. When a hole has formed in a tooth, no pain is felt until the cavity be reached and the nerve exposed, and then, as almost every one knows by experience, the pain is most excruciating. Sometimes it is relieved by some powerful stimulant dropped into the tooth, as the essential oil of cloves,—sometimes by the recently discovered substance called *creosote*, which has the property of deadening the nerve, —and sometimes the tortured victim is glad to appease the tormentor by actually destroying the nerve, by the introduction of a hot wire. If the cavity be not large, it ought to be stopped, an operation which generally succeeds in preserving the tooth for a long time, by excluding the air and all other agents which could act upon it. This stopping ought to be done with gold leaf, and by a respectable dentist; and no one should trust his teeth to the hands of the advertising charlatans, whose object, to secure constant employment to themselves, is not to preserve, but to destroy. If stopping the tooth be not successful in preventing the recurrence of toothache, the offending member must be removed; and this last resource should never be deferred so long that the stump requires to be dug out of the jaw; because then, what is a brief though painful operation, is converted into one which is tedious, and often insufferable.

The teeth at first lie deep within the jaw-bones, and are covered at birth by the thick gum. Their rudiments at birth are very small. The crown or upper part of the tooth is formed first, then the body, then the enamel is deposited on the crown, and lastly, the fangs grow as the tooth becomes protruded. When the jaw of a new-born child is dissected, a pulp is found for each tooth, like a little stool, into which bloodvessels are seen running, on the top of which the bone is deposited; and after the tooth has attained its shape, the pulpy stool shrinks away almost to nothing, except the small quantity of cellular tissue which conveys the vessels and nerves into the central cavity. The whole tooth is enclosed within a delicate membrane, which becomes ruptured when the tooth bursts forth. The gum of an infant has a sharp line running along it, which serves it to catch anything that is put into its mouth; and this line becomes broader and flattened, and finally disappears, previous to the eruption of the teeth. The order of eruption is generally the following:—First, the two central incisors of the lower jaw appear, then the corresponding ones above; next, the lateral ones below, then the corresponding ones above. After this, the order is not regularly backwards, for the foremost of the two grinders now appear below, then those above, then the eyeteeth below, then the corresponding ones above, and lastly, the second grinders come through about the end of the second, or beginning of the third year. When they do not follow this order, dentition is generally attended with more than usual irritation.



The period when the teeth appear varies very much. The author knows one lady who was born with teeth, and has seen a child born with a couple, and every one knows what Richard III. says of himself on this subject. It is rather early for them to appear at the age of four months; more commonly seven have passed before any signs of uneasiness are manifested, and sometimes even twelve or thirteen. A good deal of constitutional disturbance generally attends teething: the mouth is hot, the gums itchy, and the infant rubs them with anything it can get into its hands. For this purpose nothing is so good as the common ivory ring; all manner of corals and bells should be discarded, as they are apt to injure the mouth, or even to be thrust into the eyes. The bowels are apt to become deranged, and require constant attention. But nothing does the infant so much good as scarifying its gums. It is quite a mistake to suppose that this trifling operation gives pain; on the contrary, it is a source of instantaneous relief, and should be resorted to as often as the child manifests any signs of uneasiness. When this is neglected, teething is apt to bring on bowel-complaints, convulsions, and even that most intractable of diseases, water in the head.

From the hardness of the teeth, they are not capable of growing, so as to fill up the increased size of the jaws in after years. Hence we see a growing child come to have spaces left between its teeth, as they are removed from one another by the elongation of the jaw. About the end of the seventh, or beginning of the eighth year, a third grinder on each side of each jaw makes its appearance, which is the first permanent tooth, and never changes. When this one is rising above the gums, the central incisors of the under jaw are becoming loose. If a jaw-bone be dissected at this period, and its outer part be filed away, a very beautiful preparation is obtained. The first teeth are seen in their places, and the second set are seen deep in the jaw, below, and rather behind them, ready to rise up and supplant them. (The figure represents the right half of the lower jaw, containing the five milk teeth, and filed away so as to display the bags in which the second set are contained.) It is, however, quite

a mistake to suppose that the new teeth push out the old; the fact is, that they cannot get up until the old ones be removed.

Preparatory to the removal of the old ones, their fangs become absorbed, so that they are not a quarter of an inch in length; whereas, had they been examined some months sooner, they would have been found three times as long.

Some time between the completion of the seventh and eighth year, the second dentition commences. The first permanent grinders appear, and the central incisors fall out and are replaced. In three months more, the lateral incisors follow. In from six to twelve months more, the grinders give way, and after them the eye-teeth. The grinders are succeeded by a new species of teeth, which do not exist in the milk set, called the small grinders. These changes take place about the tenth or eleventh year, and it is not for two or three years more that the second of the permanent grinders makes its appearance. A long interval now succeeds, and the jaw acquires its full proportion, and about the ninteenth or twentieth year the wisdom-tooth cuts the gum, but sometimes not till even a later period. The author has met two instances of persons getting their wisdom-teeth at the age of thirty, and in one of these they were quite decayed before they had actually become visible. The grinders often give a good deal of pain in coming through, on account of their broad surfaces meeting with much resistance, and much relief is obtained by having the gum freely scarified.

MATHEMATICS.

CHAPTER XIII.

RULE OF THREE.

Definition I.—When two magnitudes are compared with each other by finding the number of times that the one is contained in the other, that is, by dividing one of them by the other, the resulting quotient is called their *ratio*. Thus 3 is the ratio of 12 to 4, since 3 is the quotient of 12 divided by 4, and which is usually indicated by writing 12 : 4. It is manifestly indifferent, however, in this mode of comparison, whether we say that the first of the numbers (12) is triple of the second (4) or that the latter is a third of the former; hence we might, with equal correctness, call $\frac{1}{3}$ the ratio of 12 to 4. In this we only suppose the order of division or comparison to be changed, and instead of considering 12 : 4, we take the quantity in the order 4 : 12, supposing that we make it a general rule to divide the first of the numbers enunciated by the second.

Definition II.—When the ratio of two numbers is the same with that of two others, these four quantities form a *proportion*, which results from the equality of two ratios. Thus, the ratio of 15 to 5, and of 18 to 6 is 3; and, accordingly, these numbers constitute a proportion which we write as follows:—

$$15 : 5 :: 18 : 6, \text{ or } \tfrac{15}{5} = \tfrac{18}{6}.$$

We commonly make use of the first of these forms of expression, although the last is in some respects the most convenient. The meaning given by both forms of the notation is, that the quotient of 15 divided by 5, is equal to the quotient of 18 divided by 6, that is, the ratio of 15 to 5, is equal to the ratio of 18 to 6. But the formula of enunciation is this:—as 15 is to 5, so is 18 to 6; or, more shortly, 15 is to 5 as 18 is to 6. All these forms of expression are equivalent.

The four numbers being proportioned in the order written, the terms 15 and 6 are called the *extremes*, and 5 and 18 the *means* of the proportion; and since $\frac{15}{5} = \frac{18}{6}$, it follows from the nature of fractions, that $15 \times 6 = 5 \times 18$; that is, the product of the extremes is equal to the product of the means. It is also obvious, from the same principle, that we may multiply or divide the pairs of terms 15 and 5, and 18 and 6 by any numbers, without destroying the equality of their ratios. Thus, multiplying the first pair by 2, and dividing the second pair by 3, we obtain the proportion 30 : 10 :: 6 : 2, the common ratio of which is 3 as before. The product of the extremes is likewise still equal to the product of the means, and this conditiou being maintained, the proportion is not destroyed.

From this condition of equality of the products of the extremes and means, it immediately follows that the fourth term of the proportion must be equal to the quotient resulting from the division of the product of the means divided by the first term. Thus, taking the last proportion stated, the product of the means is 10×6, or 60, and the quotient of 60 by 30 the first term, is 2 the last term. From this, it follows that, if the last term of a proportion be wanting, it may be found by a process of multiplication and division; and this process, simple as it is, constitutes the extensive rule in commercial arithmetic, popularly denominated the Rule of Three, because in it three quantities are given, and a fourth is required to be found. As an illustration let us take the following question:—

An engineer having finished 100 yards of work in a certain number of days, with 5 men, how many yards may he finish of a like quality of work in the same time with 8 men?

Here, it must be observed, that there are two quantities of the same sort, namely, 5 men and 8 men; and a third of another sort, namely, 100 yards, but the answer required by the question is of the same nature as this last, namely, yards. Let therefore this number of yards be in the meantime denoted by x. Then, in order that these four terms may constitute a proportion, the ratios of the pairs must be equal to each other,—that is,

$$\overset{\text{men.}}{5} : \overset{\text{men.}}{8} :: \overset{\text{yards.}}{100} : \overset{\text{yards}}{x}.$$

But, regarding the numbers expressing these quantities as abstract, then the value of x is found, as explained above, by dividing the product of the two means by the first term,—that is,

$$x = \frac{8 \times 100}{5} = 160.$$

The quantity x is therefore equal to 160 yards, the fourth term of the proportion, which will now stand as follows:—

$$\overset{\text{men.}}{5} : \overset{\text{men.}}{8} :: \overset{\text{yards.}}{100} : \overset{\text{yards}}{160},$$

and the proof that this proportion is correct is, that the product of the extremes is equal to the product of the means.

From this we may infer that the sole difficulty of solving questions by this rule consists in placing the numbers contained in the question in their proper order in the proportion; and this depends upon a correct interpretation of the conditions stated. The process of reasoning is, however, very simple. In the first place, we ascertain, from the nature of the question, whether the solution depends upon a proportion; and this is the case when it has two terms of the same kind, which may be either multiplied or divided by the same number, without making any change in the nature of the problem;* and a third quantity, which is of the same kind as the answer sought. We next consider whether the answer ought to be a greater or less quantity than the *odd* term; that is, whether the unknown term, which is to be found, ought to be greater or less than that of the same sort which is given; and from this we determine which of the two given terms of the same kind ought to be placed first in the proportion—the least being placed first, as the divisor, when the answer ought to be greater than its corresponding term; and *vice versâ*. Thus, in the preceding question, having set down 100 yards : x yards, we see that 8 men must, of course, do more work than 5 men; consequently, x must be greater than 100; and hence, of the two numbers, 8 and 5, the last must be placed first, as above. The following two questions will serve further to illustrate this:—

A piece of work can be done in 5 days by 57 men: in how many days ought the same to be completed by 19 men? This is manifestly a question of proportion; since we might take two or three times as many days, and as many times fewer workmen,

* It may happen that a problem has two terms of the same nature, or, as mathematicians express it, two homogeneous terms; and yet not admit of multiplication or division by the same number, without changing the conditions of the question. Thus, the time of a stone's falling to the ground is not doubled when the height is doubled; and a vessel of water is not three times longer in emptying itself when its capacity is triple. Elements of that nature, although homogeneous, cannot therefore enter as terms of a rule-of-three questiou.

without any change in the problem. Again our odd term is 5 days, and the answer sought is x days; and since a greater number of days must obviously be allowed to 19 men than to 57 men, to accomplish the same amount of work, it follows that x is greater than 5; and consequently, of the two numbers, 19 and 57, the former is the first term of the proportion. The statement is, therefore, as follows:—

$$\overset{\text{men.}}{19} : \overset{\text{men.}}{57} :: \overset{\text{days.}}{5} : \overset{\text{days.}}{x} = \frac{5 \times 57}{19} = 15$$

Six yards of cloth, $\frac{3}{4}$ wide, were required for a certain purpose; how many yards are necessary, the width being $\frac{2}{3}$? Although in this question the four terms are all yards, we see that in one case they represent length, and in the other breadth; and that 6 yards and the unknown quantity are of the same kind—namely, length. The second pair of terms of the proportion is, therefore, 6 yds. : x yds. Also, the broader the cloth, the less must be the length necessary; and $\frac{3}{4}$ being greater than $\frac{2}{3}$, we must find x greater than 6. Consequently, $\frac{2}{3}$ must be the first term, and $\frac{3}{4}$ the second of the proportion; thus, $\frac{2}{3} : \frac{3}{4} :: 6 : x$. But as the first ratio will not be changed by multiplying its terms by the same number, we may get rid of the fractional form in which these terms are expressed, by multiplying them by a multiple of their denominators; that is, by 3×4, or 12. This multiplication being performed, the proportion becomes

$$8 : 9 :: 6 : x, \text{ when } x = \frac{9 \times 6}{8} = 6\tfrac{3}{4}$$

That is, $6\frac{3}{4}$ yards of cloth, of $\frac{2}{3}$ yd. wide, are equivalent to 6 yards of $\frac{3}{4}$ yd. wide.

It often happens, especially in commercial questions, that the terms given consist of various denominations. This has the effect of rendering the calculation more lengthy; but it in no way affects the principle. Thus, suppose we have this question:— What is the price of 18 yds. 2 qrs. 2 nails of cloth, at the rate of 3 yds. 2 qrs. for £1 16s.?

Here the term sought is money, the corresponding term being £1 16s.; and since 18 yds. 2 qrs. 2 nails will cost more than 3 yds. 2 qrs., we make the least of these quantities the first term. The statement is, therefore, this:—

3 yds. 2 qrs. : 18 yds. 2 qrs. 2 nls. :: £1 16s. : £x.

But as we cannot multiply and divide by the first terms in their compound state, and as they admit of multiplication without affecting the question, we reduce them both to the same denomination; namely, *nails*. We also reduce the third term to the lowest name contained in it; namely, *shillings*. The statement, thus modified, is as follows:—

56 nails : 298 nails :: 36 shillings : x shillings.

We might now proceed to multiply 36 shillings by 298, and to divide the product by 56; by which we would find the value of $x = 191\frac{32}{56}$ shillings. But, observing that the first and second terms are both divisible by 2, we perform that operation, which does not affect the ratio; and the statement is reduced to the following:—

28 nails : 149 nails :: 36 shillings : x shillings.

We might solve the question also with these numbers, from which we would find $x = 191\frac{16}{28}$ shillings as before; but, since the first term is a divisor, and the third a multiplier, it will evidently not affect the value of x; that is, the answer sought, to divide these terms by 4, and, this done, the proportions is as follows,

7 nails : 149 nails :: 9 shillings : x shillings,

and this is not suceptible of further reduction without introducing fractions. To find x then, we have

$$x \text{ shillings} = \frac{9 \text{ shillings} \times 149}{7} = 191\tfrac{4}{7} \text{ shillings} = £9 \text{ 11s. } 6\tfrac{3}{4}\text{d. } \tfrac{3}{7}$$

The compound quantities in this question might have been converted into fractions, and the operations performed by the rules for multiplying and dividing fractions, thus,

$$\overset{\text{yards.}}{3\tfrac{1}{2}} = \tfrac{7}{2} : \overset{\text{yards.}}{18\tfrac{5}{8}} = \tfrac{149}{8} :: £1\tfrac{4}{5} = £\tfrac{9}{5} : £x,$$

$$\text{whence } x = £\frac{9 \times 149 \times 2}{7 \times 8 \times 5} = £\frac{2682}{280} = £9 \text{ 11s. } 6\tfrac{3}{4}\text{d.} \tfrac{3}{7}$$

Or the quantities might have been converted into decimals, and the operations performed by the rules for decimals, thus,

3·5 yds. : 18·625 yds. :: £1·8 : £x,

and, dividing the first two terms by 5, this becomes

·7 yds. : 3·725 yds. :: £1·8 : £x

$$\text{whence } x = £\frac{1{\cdot}8 \times 3{\cdot}725}{{\cdot}7} = £\frac{6{\cdot}705}{{\cdot}7} = £9 \text{ 11s. } 6\tfrac{3}{4}\text{d. } {\cdot}42857\ldots$$

From the preceding operations it then appears that the first and second terms must be of the same kind and denomination, and that the third term may be reduced to any denomination which may be the most convenient; observing that the answer will be a quantity of the same name. The first and second terms, and also the first and third terms may be multiplied or divided by any number without affecting the answer—which allows of the terms being reduced, and the operation abridged or made more convenient. No precise rule, however, can be given for the performance of these modifications; and it depends entirely upon the ingenuity of the student, to detect when they are applicable, and to what extent.

Sometimes the proportion appears deficient in the number of its terms, as in the following question:—

A ship's crew have provisions left for 10 days' rations, but wish to remain at sea for 15 days; to what must each ration be reduced? Here we do not find four terms; but it is evident that one of them is understood, and that the problem is equivalent to the following:—The ration 1 would be given to each man were they to remain at sea 10 days; but, as they are to be at sea 15 days, what fraction of the ration 1 should be allowed him? The statement is obviously $15 : 10 :: 1 : x = \frac{2}{3}$.

Similarly—If a reservoir be filled by one pipe in 6 hours, by another in $5\frac{1}{4}$ hours, and by a third in $4\frac{2}{3}$ hours; in what time will it be filled by the three pipes all running together? The first consideration here is the portion of the reservoir which is filled by the first pipe in 1 hour, that is this question: If the whole be filled in 6 hours, what part will be filled in 1 hour? In answer, we have 6 hrs. : 1 hr. :: $1 : x = \frac{1}{6}$. And similarly for the other two, we have

$5\frac{1}{4}$ hr. : 1 hr. :: $1 : x = \frac{4}{21}$; $4\frac{2}{3}$ hr. : 1 hr. :: $1 : x = \frac{3}{14}$.

Thus, the three pipes running together will in 1 hour fill this fraction of the reservoir, viz., $\frac{1}{6} + \frac{4}{21} + \frac{3}{14}$, that is, $\frac{7}{42} + \frac{8}{42} + \frac{9}{42} = \frac{4}{7}$; and the question now becomes: If $\frac{4}{7}$ of the reservoir be filled in 1 hour, in what time will the whole bo filled? It will evidently require more than 1 hour: the proportion is therefore as follows,

$\frac{4}{7}$ (of cap. of reservoir) : 1 (whole cap. of reservoir) :: 1 hr. : x hr.

whence $x = 1$ hr. $\div \frac{4}{7} = 1$ hr. $\times \frac{7}{4} = \frac{7}{4}$ hr. $= 1\frac{3}{4}$ hr.; that is, the three pipes will, when all running together, fill the reservoir in $1\frac{3}{4}$ hour.

Questions of this kind may, however, be resolved independently of the rule of three: thus unity (1) being divided by the times in which the reservoir would be filled by each of the pipes separately, gives the fractions of it which they would severally fill in the given unit of time; and that unit, being divided by the sum of the fractions of the whole capacity thus filled, gives the whole time. For instance, in the question above, the times are 6 hours, $5\frac{1}{4}$ hours, and $4\frac{2}{3}$ hours, and 1 divided by each of these quantities gives the fractions $\frac{1}{6}, \frac{4}{21}, \frac{3}{14}$, the sum of which, as found above, is $\frac{4}{7}$; and 1 hour, divided by $\frac{4}{7}$, gives $1\frac{3}{4}$ hour as before.

It frequently happens that questions contain more than three given quantities. When these consist of two periods in which the terms are respectively of the same kind, and vary proportionally, the question constitutes what is termed a *compound proportion*, and its solution belongs to the DOUBLE RULE OF THREE. The following is an example:—

If 20 men can build 160 yards of wall in 15 days, how many yards ought 30 men to build in 12 days? Here the 20 men and 15 days may be regarded as associated agencies in producing the effect expressed by 160 yards, and 30 men and 12 days in producing the effect x yards to be found; but the efficiency of 20 men working 15 days may be expressed by 20×15 or 300 and the efficiency of 30 men working 12 days by 30×12 or 360. Now as 160 yards is the effect produced by 300, it is obvious that x must be greater than 160 yards, since the agency to effect

by night; their beaks were long, and armed with sixty sharp conical teeth, but their most remarkable character consisted in the excessive prolongation of the second toe of the fore foot, which was fully twice that of the trunk, and is supposed

Pterodactylus crassirostris—restored by Goldfuss.

to have supported some membrane which enabled the animal to fly. The fingers terminated in long hooks, like the curved claws of the bat; the form and size of the foot, leg, and thigh, show that it was capable of standing either firmly on the ground, or of perching on the branches of trees. Dr. Buckland also conjectures that it had the powers of swimming. Thus like Milton's "all qualified for all services and all elements," the creature was a fit companion for the kindred reptiles that swarmed in the seas or crawled upon the shores of a turbulent planet.

> "The fiend,
> O'er bog or steep, through strait, rough, dense, or rare,
> With head, hands, wings, or feet, pursues his way,
> And swims, or sinks, or creeps, or flies."

"With flocks of such like creatures flying in the air, and shoals of no less monstrous Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic crocodiles and tortoises crawling on the shores of the primeval lakes and rivers; air, sea, and land must have been strangely peopled in those early periods of our infant world."

Hylæosaurus (Weald Lizard). The lizard thus denominated by the discoverer, Dr. Mantell, was about twenty-five feet in length, and is chiefly remarkable by a large spiny process along the back, which must have given to such a creature a terrific appearance. Such process is found in many of the living lizards.

Iguanodon.—The remains of this, the most gigantic of all reptiles living or extinct, were also made known to the world by Dr. Mantell. The bones obtained by the Doctor indicate the existence of an herbivorous lizard, allied in struc-

The Iguanodon—restored.

ture to the iguana of the West Indies; seventy feet in length, and four and a half feet in circumference round the body. A thigh bone measures three feet eight inches, and thirty-five inches in circumference, and the bones of the foot show it

to have been six and a half feet in length. The nose of the animal was armed with a horn, equal in size, and resembling in form the lesser horn upon the nose of the rhinoceros,—an apparatus which also exists on the nose of the iguana. The teeth, some of which are two and a half inches in length, are deeply serrated, and their resemblance to those of the iguana, clearly demonstrate that, like it, it was of herbivorous habits. Besides the remains found in Talgate forest, in strata of the Wealden formation, Dr Mantell mentions the discovery of another at Maidstone, in an arenaceous or sandy limestone, called Kentish rag, belonging to the Shanklin sands. This rock, he observes, abounds in the marine shells, which are characteristic of that division of the chalk formation. In the quarry in which the remains of this Iguanodon were found, Mr Benson has discovered fossil wood by the boring shells, the lithodomi; impressions of leaves, stems of trees, ammonites, nautili, &c.; large conical striated teeth, which are referrible to those extinct fossil fishes which M. Agassiz denominates sauroid, or lizard-like; scales and teeth of several kinds of fishes, and among these a jaw or mandible of that singular genus of fish, the Chimera.

The geological position of this specimen forms an exception to what has been previously remarked of the fossils of the Wealden; for, while the bones in the latter were associated with terrestrial and fluviatile remains only, the Maidstone specimen is imbedded in a marine deposit. This discrepancy nowise affects the arguments as to the fluviatile origin of the Wealden; it merely shows that part of the delta had subsided, and was covered by the chalk ocean, whilst the country of the iguanodon was still in existence. The body of the iguanodon was then drifted out to sea, and became imbedded in the sand of the ocean; in the like manner, as at the present day, bones of land quadrupeds may not only be ingulphed in deltas, but also in the deposits of the adjacent sea. This specimen, continues the Doctor, clearly proves that the separate bones found in the strata of Talgate forest, and which I had assigned solely from analogy to the lizard tribe, have been correctly appropriated, and we obtain many interesting facts relating to the structure and economy of the original. I can but notice one of these inductions. As the iguana lives entirely on vegetables, it is furnished with long slender feet by which it is enabled to climb trees with facility in search of food. But no tree could have borne the weight of the colossal Iguanodon; its movements must have been confined to the land and water, and it is evident that its enormous bulk must have required limbs of great strength. Accordingly, we find that the hind feet of the hippopotamus, rhinoceros, and other large mammalia, are composed of strong short massy bones, furnished with claws, not hooked as in the iguana, but compressed as in the land tortoises, thus forming a powerful support for the enormous leg and thigh. But the bones of the hands or fore-feet, are analogous to those of the iguana—long, slender, flexible, and armed with curved claws, the exact counterpart of the nail-bones of the recent animal, thus furnishing prehensile instruments fitted to seize the palms, arborescent ferns, and dragon-blood plants, which probably constituted the food of the original. Thus we have another interesting example of that admirable adaptation of structure to the necessities and conditions of every form of existence which is alike manifest, whether our investigations be directed to the beings around us, or to those which have long since passed away.

We must defer entering upon a description of the other organic forms, peculiar to the secondary formations, till our next.

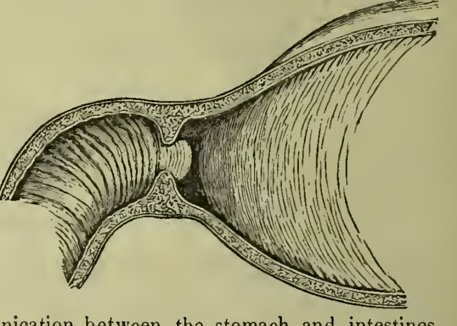
⁂ (1) Septarian: concretionary masses of limestone or ironstone, with intersecting veins of spar or iron pyrites. (2) Cephalopods: mollusca, which have their organs of progression and prehension arranged round the head like the nautilus and cuttle-fish. (3) Trigonia, a triangular formed bivalve; cerithium, a species of screw shell with a notched aperture; isocardia, a heart-shaped shell resembling the cockle (cardium).

ANATOMY AND PHYSIOLOGY.

CHAPTER XVIII.

OF DIGESTION.

THE *stomach* is a bag of a conical shape, the large end of which lies in the left side of the belly immediately beneath the diaphragm, and the small end at the hollow which is familiarly known as the pit of the stomach. It is bent, besides, on account of its passing across the spine; the concave border being directed backwards, and the convex border forwards. When the stomach is nearly empty, the convex border hangs downwards, and when filled, it rises forwards, producing sometimes a painful feeling of distension. This is most felt by persons who are troubled with flatulence after taking food. In such persons, if one finger be laid over the stomach, and struck with one of the other hand, it will sound like a drum, in consequence of the quantity of air which is contained within it. There is always, however, a certain quantity of gas in the stomach and whole course of the intestinal canal. The gullet enters the greater or left end of the stomach, and the small intestine commences at its smaller or right end. These two orifices are upon the same level, so that the food does not run out of the stomach, but can get out of it only by the contraction of its coats. These are muscular, as indeed are the coats of the whole intestinal canal, and are particularly strong at the smaller end, where they form a ring, which contracts, and completely closes the



communication between the stomach and intestines. The stomach is lined with a velvety mucous membrane, similar to, and continuous with, that which lines the mouth and gullet. This membrane is full of minute blood-vessels, from which the mucous fluid is poured, which serves at once to mingle with the food and assist its digestion, and to prevent the coats of the stomach from injury. Accordingly, when any irritating substance is swallowed, more mucus is immediately poured out, which envelopes it, and prevents as far as possible the evil consequences which might ensue.

Besides the mucus, another fluid is poured into the stomach by its coats, which is called the *gastric juice.* This is a clear ropy fluid, of a saltish taste, possessing the power of dissolving all substances which are fit for food. It has no effect, however, on the living stomach; but we often find, on opening persons who have died suddenly, with a quantity of the gastric juice in the stomach, and no food, that the dead stomach itself has been dissolved, and that a large irregular opening exists in its back part.

After a meal, the stomach becomes agitated by a constant succession of gradual contractions, which turn the food gently from the left side to the right, and back again, churning it and mixing it all well together, so that it acquires the appearance of so much porridge or gruel, the different aliments that have been swallowed becoming so blended as to form a homogeneous mass of a grayish colour. It is turned back-

ward and forward for three hours or more, until the delicate sense, which resides in the orifice leading into the intestines, is satisfied that it is fit to pass farther; the constricted ring then opens to let it through, and it passes into the commencement of the bowels. But such is the delicacy of perception with which the outlet of the stomach is endowed, that it will not let undigested food pass, until it has been rolled about in the stomach for many hours, and presented to it and rejected many successive times. Indeed, it often refuses to allow such food to pass at all; and then there is no help for it but that it be ejected summarily by vomiting.

Let us now inquire into that part of the process of digestion which goes on within the stomach.

In this organ the first of these changes takes place which fits the extraneous matter swallowed as food, for being received into the circulation of the fluids of the living body, and for becoming a component part of the animal. For now the gastric juice, acting on the semifluid mass, gradually dissolves out the digestible part, and, entering into union with it, produces a new, thick, turbid fluid, which has been called *chyme*. The alimentary mass changes its sensible and chemical properties by an operation peculiarly animal, or depending on the existence of life. The change is not strictly chemical; for we do not find anything like it going on out of the living body. Animal or vegetable matters, in any vessel possessing the heat and moisture of the stomach, would quickly fall into fermentation and become sour, but the living properties of the stomach prevent this. No superfluous acid is formed in the stomach in the healthy state; but when it is weak, and its nervous action deranged, then the symptoms which announce the diminished power are the extrication of gas, and abundant formation of acid, with oppression and uneasy sensations. The stomach having been stimulated by fulness, both of food and wind, and still more by the peculiar excitement caused by the food undergoing digestion, its muscular coat is brought into action, and its contents delivered over into the commencement of the small intestine.

We are solicited to take food by the uneasy sensation of *hunger*,—a sense which appears placed as a safeguard, lest the body should be permitted to wear out. In the artificial state of society in which we live, where regular hours are appointed for meals, so that one shall succeed before the interval after the preceding shall have been so long as to produce pain, no one almost knows what hunger really is, except by some self-inflicted abstinence on a fishing or shooting excursion. Yet though unaccustomed to be felt by us, there is an unpleasant sensation produced by want of food, amounting at first only to a feeling of emptiness, lassitude, and indescribable uneasiness, but gradually getting worse until it end in actual pain, as if the inward parts were all on fire. There was a time when it was thought that the internal surfaces of the empty stomach rubbing against one another produced hunger; and hence arose the vulgar phrase of "taking the wrinkles out of your stomach," by satisfying the appetite; but that is too mechanical an explanation. If the sensation proceeded merely from such rubbing of the coats of the stomach, food swallowed would be more likely to aggravate than to assuage the gnawing of hunger; to excite the action of the stomach would be to excite the appetite; and an irritable stomach would be attended with an insatiable desire of food. But something more than mere emptiness is required to produce hunger. By some of the ancients, hunger was referred to the weight of the liver dragging down the empty stomach, forgetting that the liver is as heavy, and will drag as much, when the stomach is full as when it is empty. By others, with more probability, it is supposed to proceed from the action of the gastric fluid on the nerves in the coats of the stomach. Hunger is like thirst, a *sense* placed as a safeguard to call for what is necessary for the system, and depending on the general state of the body. Morbid craving may proceed from many causes; a tape-worm in the bowels has occasioned voracious appetite, and ardent spirits and high seasoning excite it even when the stomach is full; but natural hunger has always a reference to the wants of the general system.

Thirst is a sensation seated in the tongue, throat, gullet, and stomach. It depends on the state of the membrane which lines these parts, and of the fluids which naturally moisten it, and may arise either from a deficiency of that fluid, or from an acrid state of it. It would appear to be placed as a monitor calling for the dilution of the fluids by drink, when they have been exhausted by perspiration and the fatigue of the body, or when the contents of the stomach require to be made more fluid, the more easily to suffer the necessary changes of digestion. The feeling of thirst, when carried to an extreme, is said to be much harder to bear than that of hunger; and the most dreadful picture is given of it in some accounts of shipwrecks, particularly in that published of the horrible calamities endured by the crew of the French frigate, the Medusa, on the coast of Africa.

The changes which take place on the tongue, in consequence of the state of the stomach and intestines, depends on its intimate connexion with these organs, and the nervous sympathy which is established between them. The state of the tongue, the loose or viscid state of the throat, the secretion of the saliva, the softness or huskiness of the voice, are all influenced by the state of the stomach. We attend more to the effects on the tongue than to any of the rest, because it is more accessible, and affords us a sort of index to the state of the stomach. In health, it is clean, red, and moist; in indigestion, it is white; in disorders of the bowels it is more or less thickly furred; after excess in wine, it is dry and chopped; and in bad cases of fever, it becomes quite black.

A great deal of nonsense has been written, and a great many absurd experiments have been performed, with the view of elucidating the nature of digestion on the one hand, and the digestibility of various kinds of aliment on the other. A very curious case, however, occurred in America, by which immediate access was had to the living stomach, and the experiments which were performed have been published by their author, Dr. Beaumont of Plattsburgh, in the state of New York.

A young man, of good constitution, when eighteen years of age, was accidentally wounded in June, 1822, by a musket loaded with buck-shot fired close beside him. The shot tore away a piece of his left side, about a handbreadth in extent, making a hole in his stomach. For seventeen days everything that was taken by the mouth passed out at the hole; but after that period, by means of properly adapted bandages, the food was enabled to be retained. The wound gradually diminished, until it became of the size and nearly of the appearance of the natural anus, the lining membrane of the stomach joining the skin all round; and about a year and a half after the accident, the membrane came to form a sort of valve, which prevented anything from running out, although it readily permitted the finger, or a tube, or a tea-spoon, to be introduced. By two years after the accident, he had completely recovered his health and strength; and Dr Beaumont conceived the idea of making use of the extraordinary opportunity thus put in his hands, of examining into the nature of digestion.

When the stomach was empty and at rest, the interior of its cavity could be examined to the depth of five or six inches, and food and drink could be seen entering it through the ring at the entry of the gullet. The solvent power of the gastric juice was ascertained in the most conclusive manner. Almost every variety of aliment, whether animal or vegetable, when submitted to the action of the fluid taken from the stomach when fasting, and kept at the temperature of about 100°, was found to become in a few hours reduced to a paste, which resembled very nearly the contents of the stomach after the same kinds of aliment had been eaten. The rapidity with which substances were dissolved by the gastric fluid out of the body, was always in proportion to the purity of the fluid, and the tenderness and state of minute division of the substances submitted to its action. Milk and the white of egg

were invariably found to become first curdled by the fluid, and then dissolved.

The periods required for the solution of various substances in the gastric juice, out of the body, varied as follows:—Sago and tapioca, boiled, were completely dissolved in about three hours and a quarter; fresh bread, in about four hours and a half; milk, in about the same time as bread; calf's-foot jelly, in about four hours and three-quarters; soft-boiled eggs in six hours and a half; hard-boiled, in two hours longer; oysters, raw and entire, seven hours and a half; stewed, eight hours and a half; beef-steak, in eight hours; boiled beef, in nine hours and a half; boiled mutton and raw pork, in eight hours and a half; beef suet, boiled, in twelve hours; mutton suet, boiled, in ten hours; cream, in twenty-five hours and a half; olive oil, in sixty hours. In these experiments the gastric juice employed was about eight times the quantity of the substance to be dissolved. It will be seen from these experiments, that fat and oily food was among the articles which presented the greatest resistance to the solvent powers of the gastric fluid; and Dr Beaumont found this to be the case in the stomach as well as out of it. Some of his experiments indicate that the digestibility of this sort of food is facilitated by a slight admixture of bile with the gastric juice, and that very generally, when aliment containing fat is eaten, bile passes up into the cavity of the stomach.

The following are the conclusions which Dr Beaumont has deduced from his experiments on his patient:—

"The ordinary time required for the complete digestion of the food received into the stomach, in a healthy state of that organ, is generally three hours and a half. The facility of digestion is modified, however, by many circumstances, as the peculiar nature of individuals, their habits, the nature of the food, and the manner in which it is prepared: minuteness of division, and tenderness of fibre, would appear to be the two great essentials for the speedy and easy digestion of the aliment.

"Albumen (white of eggs,) if swallowed either raw, or very slightly coagulated, is, perhaps, as rapidly digested as any article of diet we possess. If perfectly hardened by heat, and swallowed in large solid pieces, it experiences a very protracted digestion. Fibrin (red muscular flesh,) and jelly are affected in the same way; if tender and finely divided, they are disposed of readily; if in large solid masses, digestion is proportionably retarded."

Animal fat is invariably and very quickly rendered fluid by the heat of the stomach, and. with any species of oily food, resists for a long time the action of the digestive organ and its fluids. It has already been noticed above, that this sort of food generally requires an admixture of bile (which is alkaline,) to render it soluble.

"Bulk is, perhaps, nearly as necessary to the articles of diet as the nutrient principle. They should be so managed that the one of these qualities should be in proportion to the other. Too highly nutritive diet is probably as fatal to the prolongation of life and health, as that which contains an insufficient quantity of nourishment."

A commencing state of putrefaction, sufficient to render the muscular fibre slightly tender, was found to increase the digestibility of most kinds of flesh. This is a practice which every housekeeper in this country adheres to, though without knowing the principle on which it is founded.

Vegetable aliment, generally speaking, he discovered to be slower and more difficult of digestion than animal. Its solution in the stomach is greatly influenced, however, by division and tenderness of fibre. Raw vegetables often pass through the stomach in an undigested state, while other food is retained and fully digested. Here is a hint for the eaters of salads.

The thorough mastication of the food is essential to healthy digestion. "If aliment," remarks the author, "in large masses be introduced into the stomach, though the gastric juice may act upon its surface, digestion will proceed so slowly, that putrefactive changes will be likely to commence in its substance before it will become completely dissolved. Besides, the stomach will not retain undigested masses for a long time, without suffering great disturbance." Consequently, eating too fast impedes digestion, by introducing food into the stomach in a state unprepared for the actions of that organ and of its fluids. Also, if food be swallowed too rapidly, more will in general be taken into the stomach before the sense of hunger is allayed, than can afterwards be digested with ease.

Overloading the stomach with food, is invariably found to interfere with the regular process of digestion; a portion remaining for a long while undigested. This may soon become rancid, or sour, running into the acetous fermentation; and if not rejected by vomiting, causes pain and irritation of the stomach, and other distressing symptoms; or if it be permitted to pass into the intestines, its presence almost invariably gives rise to colic, flatulence, or even more dangerous affections.

Condiments, as spices, though they may at first excite the action of a debilitated stomach, yet, when used habitually, never fail to produce debility of that organ, and in this manner impede digestion. Salt and vinegar are exceptions, and are not obnoxious to this charge when used in moderation. They both assist digestion—vinegar, by rendering muscular substance more tender—and both, by producing a fluid having some analogy to the gastric juice. Spirituous, and probably all artificial drinks, impede more or less the digestive process; some more so than others, but none can claim exemption from the general charge. Even tea and coffee, the common beverages of all classes of people, have a tendency to debilitate the digestive organs.

After a full meal, rest should be taken for at least an hour. After that, moderate exercise rather aids digestion, but severe and fatiguing exertion always impedes its performance. An experiment was made by a medical man on a couple of dogs, of the same litter, and in equal health. After giving them a good dinner of flesh, one was taken out and hunted for four hours, while the other was permitted to lie down and sleep. They were then both killed; the hunted dog had the meat in his stomach quite undigested; the idle one had it quite gone. The lesson is a most instructive one.

BOTANY.

CHAPTER IV.

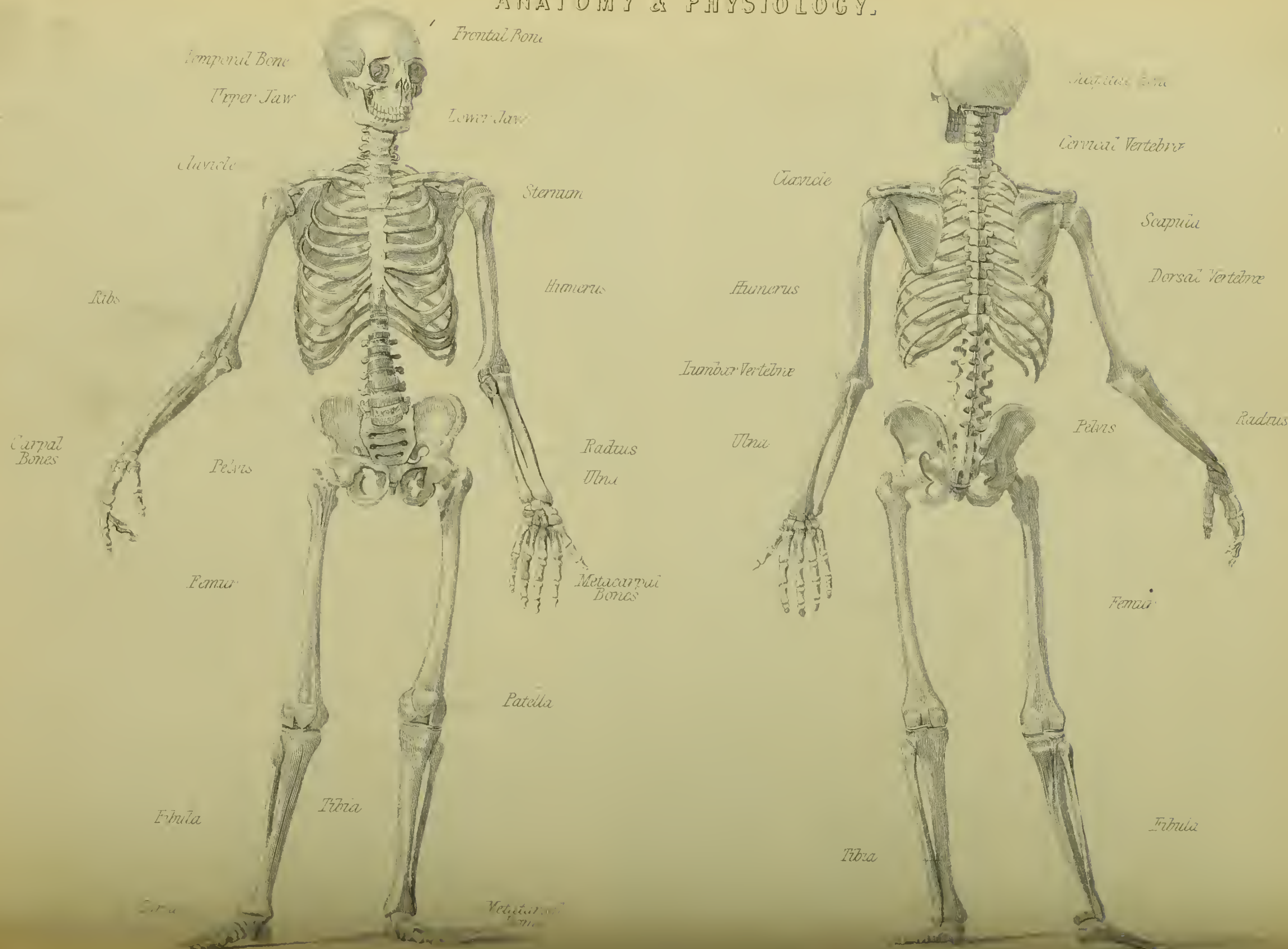
THE STEM.

It was explained in Chapter III., that the root of a plant passes downward from what is called the crown, or neck, or life-knot, where the root and stem meet, and which seems to belong indifferently to either. We have now to observe that the *stem* or *trunk*, or *ascending axis*, arises from this knot, and invariably makes its way at first more or less upward, whatever may become its subsequent direction. It passes upward from the root, getting smaller as it ascends, and so putting on the form of a cone. It gives support to the leaves, flowers, and fruit, and transmits to them the nourishing juices absorbed from the earth. These juices, it is most probable, undergo some chemical change, while passing up through the vessels of the stem.

With regard to their structure and arrangement, stems are simple, (40), as those of the white lily among flowers, and the palms among trees; or branched, as in most trees and shrubs; they may be hollow, as in the grasses and *umbelliferæ*, but more generally they are solid.

With regard to their direction, the stems of most plants *rise from the ground*, (it has been already said that they all rise *from the root*,) bearing the branches and leaves, the flowers and fruit. Most of these are able to support their own weight, and are simply described as *ascending*; some creep along the ground, as the Ground Ivy; indeed the creeping root, (28, Chap. III.) is more properly a creeping stem; some seem to fall on the ground, and are *decumbent* or *procumbent*; others have the wish to rise, but cannot support

ANATOMY & PHYSIOLOGY.



HUMAN SKELETON

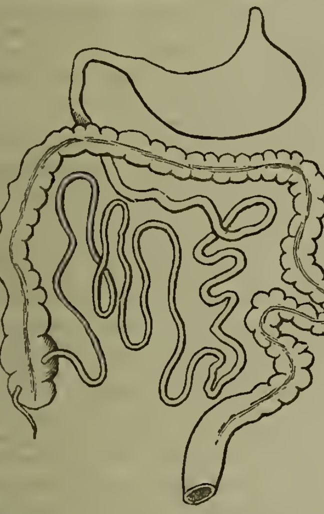
ANATOMY AND PHYSIOLOGY.

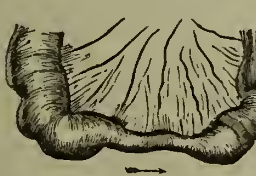
CHAPTER XIX.

THE INTESTINES.

THE *intestines* form a membranous tube nearly six times the length of the body, about five-sixths of this length belonging to the small intestines, and about one-sixth to the large. The small intestines are the canals into which the chyme is received from the stomach; and when digestion is completed, the large serve chiefly as receptacles for the refuse which is to be expelled from the body.

In the figure, the small intestine is seen commencing from the smaller or right extremity of the stomach, and passing to the right side. It lies close below the liver, and turning downward, receives from it the gall-duct, and from the *pancreas*, the duct bringing its secretion, so that these fluids may mingle with the food; then going across the spine to the left, it twists and forms a great number of convolutions which lie chiefly in the middle of the belly, round about the navel, and finally terminate in the large intestine, in the right flank. In the drawing, the turns are not represented exactly as they are placed in the belly, but as separated and spread out in order to render them distinct. Neither is the small intestine represented by more than half its proper length; otherwise the numerous convolutions would have made the whole figure quite confused. The whole intestine is lined with a continuation of the velvety membrane which lines the stomach, and which is constantly moistened by a mucous secretion. The thickness of the gut is formed of muscular fibres, arranged in two layers, as seen at the left end of the figure, the outer layer being longitudinal, and the inner layer circular. When these fibres contract, their effect is to narrow the gut, as in the middle of the figure, and at the same time to draw the portion next farther down, upward to the contracted part, over the contained food, just as one draws up a stocking over the foot that is pushed into it. The effect of the gradual and generally uniform contraction of these fibres is to propel the food downward; and if the belly of an animal newly killed be opened, the bowels are seen moving in the manner of a bunch of earth-worms creeping through among one another,—whence the name of *vermicular* motion, which has been given to it. The gall-ducts enter the small intestine about six inches after it leaves the stomach; and the moment the bile mingles with the chyme, a chemical change takes place, and the separation of the nutritious parts from the refuse begins to go on. A creamy-looking white fluid appears on the surface of the food, next to the mucous membrane, and is sucked up by an infinity of small vessels called the *absorbents*, which will be described by and by. In performing all this process, the obvious use of the great length of the alimentary canal is, that every part of the food may be turned about, and be successively presented to the mouths of those vessels, so as to have its nourishing particles fully removed. The food therefore becomes gradually thicker and drier as it passes down, and is stained of a yellow colour from the admixture of bile; but it still remains perfectly sweet, and without any bad smell, until it gets into the large intestines, where it puts on the character of *fæces*, or useless matter.





The large intestine is seen to commence by a blind end, into the side of which the small intestine opens. A valve is here placed to prevent the regurgitation of the fæcal matter into the small bowels; and this it always does, except the force exerted to overcome it be very considerable. A figure of this very curious structure would have been shown here, but it is one of those parts of which no idea can be given by a drawing to a person unacquainted with them; they require to be seen and handled before they can be appreciated, and there are many such in the body. (A similar remark, by the by, was made in describing the valves of the heart.) A curious appendage, about the size of a large earthworm, is seen hanging from the blind end of the large gut, which in man is merely rudimentary. In purely graminivorous animals, the intestines are much longer than in man, and have several of those contrivances for delaying the less nourishing food upon which they subsist, until all its useful particles can be absorbed, In carnivorous animals, again, the intestinal canal is short, because their food is so highly nutritious, that its digestion is very quickly completed. Man occupies an intermediate place between these, and his bowels, like his teeth, indicate distinctly the mixture of the food which he is intended to derive from both the animal and vegetable kingdoms. From this blind pouch, then, the great gut ascends in the right flank, crosses over the belly below the stomach, descends in the left flank, forms a twist like the letter S, and then turns into the pelvis to open outwardly at the anus.

It has already been stated that the nourishing part of the food, the *chyle*, is absorbed from the intestines by an infinity of small vessels, having a close affinity to veins. Their structure is very like that of veins, being provided with valves, giving them a knotted appearance, which prevent the fluid they convey from taking a retrograde course. They are not more than the thirtieth of an inch in diameter, and are so transparent, that they are not visible when empty. If a dog be killed about two hours after a full meal, these vessels are seen in great numbers arising from the bowels, and filled with a white milky fluid, whence they receive the name of *lacteals*, (Latin, *lac*, milk). These vessels unite at the right side of the spine into a trunk about the size of a goose-quill, which at length pours its contents, containing all the nourishment of the body, (except the watery parts which seem to be taken up by the veins,) into the great vein of the upper part of the body, at the junction of the neck with the shoulder. It will be understood from this description, that since the new fluid is poured into a vein, not into an artery, it must necessarily be exposed to the air in the lungs, along with the current of the venous blood; this process probably completing its change into blood before it is circulated over the body.

There is another set of vessels of precisely the same kind, called *lymphatics*, which are very difficult to discover in dissection, because the fluid which they convey is not milky, but transparent lymph. These arise from every part of the

body, and have for their office the removing of the worn-out parts, which are no longer serviceable, and which are to be replaced by new deposits from the blood. The lymph is poured into the duct which has been spoken of in the preceeding paragraph, and is mixed with the blood in the veins, so that afterwards it may be expelled from the body through the lungs, the liver, the kidneys, and the skin. The lymphatic and lacteal vessels are included under the common name of *absorbents.* They both pass through *glands,* which are roundish bodies (see last figure) about the size of hazel nuts, in which the absorbents subdivide and reunite, apparently for the purpose of mixing thoroughly the lymph and the chyle together.

The absorbent vessels and glands are very subject to disease in those individuals who are of a scrofulous temperament. The glands are very liable to enlarge, inflame, burst, and suppurate, particularly in the neck, armpits, and groins, and produce sores which are very tedious in healing. Sometimes in scrofulous children, the larger branches from the intestines become obstructed before they arrive at the main duct, so that all the food they eat, (and they generally have voracious appetites), never does them any good, because it never gets into the circulation. Such children are generally small and puny, with sharp thin faces, and large tumid bellies.

The whole of the contents of the belly are covered with a thin shining membrane, called the *peritoneum,* which also lines the boundary walls of that cavity. It is of the same nature as the membrane which lines the chest and covers the lungs, and as that which surrounds the heart. Its smooth polished surface is evidently intended to permit the constant gentle motions of the bowels to go on easily, without our being at all sensible of them. This surface is kept moist by a thin liquid, the evaporation of which is the reason why the body of an animal newly killed is seen to smoke when opened and exposed to the air. When this fluid is poured out in too great quantity, the bag of the peritoneum becomes distended with it, and constitutes the disease called dropsy. When medicines have no effect in reducing this, it becomes necessary to tap the patient; that is to say, to insert a small tube with a sharp point into the cavity of the belly, so as to permit the water to run out. This membrane is exceedingly liable to become inflamed, and when inflammation does come on, it runs a very rapid course, and generally proves speedily fatal. It is from this inflammation that many of those females sink, who perish after child-bearing.

Let us now devote a page to a notice of the diseases of the alimentary canal.

The stomach is rarely the seat of inflammation. It is so accustomed to have all things indiscriminately, and often recklessly, poured into it, that it would not be fit for its place in the body, if it were too easily put wrong. Many poisons, however, such as vitriol, arsenic, and corrosive sublimate, produce death by exciting in it violent inflammation. The stomach is nevertheless subject to a very low degree of inflammation, or rather irritation, which gives great uneasiness to its possessor. There are many, particularly among the female population, and these not in the lowest ranks, who can scarcely swallow any food, without its being succeeded by a feeling of distension and a sense of uneasiness, not amounting to actual pain, but as distressing as if it were, —producing headach, giddiness, coldness of the feet and of the surface generally, acidity, with eructations of gas, and sometimes the bringing up of a mouthful of fluid. These annoyances last till the three or four hours are passed, during which the food remains in the stomach. Ailments of this kind are exceedingly difficult to remove, for a plain reason, because the stomach cannot be allowed to rest; it must always go on with its work to a certain extent, and the only ease it can get is, that the aliments introduced shall be as easily digestible as possible. It is not easy to lay down any rule for this, although the account given in the preceding article of the digestibility of different substances will furnish some data; but the stomachs of those troubled with indigestion are most capricious, and we sometimes see them reject anything simple, and evince what we would consider the most extraordinary predilections. Mild laxatives, tonics, bitters, &c., all may take their turns as assistant remedies; but nothing can be persevered in long, and a constant reference to the medical attendant is necessary. Small blisters over the stomach, or crops of pustules brought out by rubbing the skin with tartar-emetic ointment, are often most beneficial.

Sometimes, after long disorder of the stomach, perforation takes place, and its contents escape into the cavity of the belly, producing violent inflammation and a hurried death. *Cancer* is a disease which attacks the stomach after the middle period of life is passed; it consists of a thickening of its coats, forming a growth which sometimes can be felt even from the outside, and generally ulcerated upon its internal surface. It produces the most distressing symptoms, burning heat, constant craving for food and drink, with inability to retain them, and at length the patient dies, worn down to a shadow.

Inflammation of the bowels takes place after exposure to cold, or the swallowing improper food. Pain marks its approach, and generally obstinate costiveness; and unless active treatment be had recourse to, the result is speedily fatal.

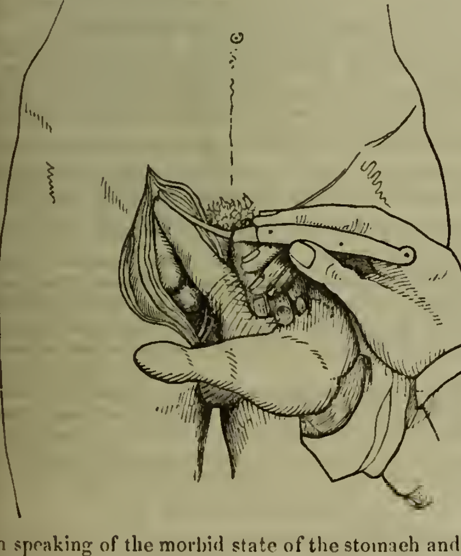
A quickened action of the bowels, hurrying through them whatever has been taken into the stomach, together with an increased quantity of the mucus which naturally moistens this lining membrane, constitutes a *diarrhœa* or looseness. This may be caused by any substance which disagrees with the stomach, especially by new vegetables when they first come in; or by a more remote cause, application of cold to the body when heated, which drives the blood in upon the internal organs. In this country, however, the lungs are the parts most apt to suffer from this last cause. Sometimes the flow of bile is much increased at the same time; and one is said to have a *bilious diarrhœa.* Then again, the lining membrane may become inflamed and ulcerated, while the purging of bile continues, mingled with blood, and attended with severe griping pains; and the patient is said to have *dysentery.* This is a complaint of hot climates, but we have it also, especially in the heats of autumn. If, again, vomiting of bile be joined to this purging, the complaint is called *cholera.* A dreadful form of this, the epidemic cholera, passed over great part of the globe a few years ago, committing great devastation in its path. It was in this country in 1832 and 1848, and the sad sufferings and deaths of their relatives and neighbours must be fresh in the memories of many of our readers.

A very painful affection of the bowels, but without danger, is *colic;* consisting of a distension of the great gut with an unusual quantity of gas, which is prevented from escaping by a spasmodic contraction of some part between it and the natural outlet. Some hot drink generally gives speedy relief. A curious form of colic is common among painters, the *lead colic,* depending on the absorption of white lead into their systems, and is accompanied by a loss of power in the muscles of the fingers and wrist.

It is a curious thing that other animals sometimes take up their abode within ours, especially in the bowels. Besides some rarer forms, there are three species of intestinal worms with which we are familiar. Hundreds of very small white ones take up their abode in children, infesting the lowest part of the gut, just within the anus, and giving great annoyance from the irritation which they cause, besides occasioning a falling away in health and strength. Worms, from five to eight inches long, are found in the small intestines in some individuals, and even make their way up into the stomach, so as to be thrown up by the mouth. A rare kind is the tape-worm, about half an inch broad, and from ten to twenty feet long; it is generally solitary; indeed, one such companion will be quite sufficient. The presence of intestinal worms is always accompanied by loss of health; strong medicines are required to drive them out, and careful attention to the state of the bowels afterwards, to discourage a second invasion.

It were a neglect did we not notice the sluggishness of the bowels, so apt to be induced in an artificial state of society, such as exists in towns. A movement of the bowels should take place every day ; but from want of time, or want of convenience, this is neglected ; the daily call is not attended to, and by and by it ceases to be made. A necessity is now felt for medicine, and this is repeated day after day, and week after week, until the health is seriously and permanently injured. There are plenty of pills prescribed by the regular, and advertised by the irregular practitioner, many of which are good and useful; but care should be taken to have proper ones recommended at first, and not to persevere too long in the use of the same ones, as the bowels become habituated to the repetition of the same stimulus, and require a new one. The use of the enema syringe, by which warm water is thrown into the gut, so as to procure an evacuation, has become very common of late years, and is very good ; for it secures the stomach and small intestines from the irritation of constantly repeated doses of medicine. The instrument, with directions for use, may be had at a very moderate rate from all the surgical instrument-makers.

A not uncommon complaint connected with the belly, particularly among the labouring population, is *rupture*. This consists in a portion of the bowels being forced out from its natural position, through some weak point in the walls of the belly, forming a swelling, covered by the skin. This swelling requires to be pressed up into the belly, and means must be used to keep it from coming down again. The apparatus used is generally a truss, consisting of a steel spring covered with leather, which goes round the waist, having a pad on one end, for making pressure on the weak part. Sometimes the rupture becomes strangulated; that is to say, it swells so that it cannot be replaced, and then it would mortify; so that death would be the inevitable consequence, were not an operation had recourse to, by which the stricture or edge of the opening is divided, so that the protruded parts are got returned. This is one of the most delicate operations in surgery, and fortunately, when it is had recourse to in time, it is one of the most successful. The wood-cut represents the surgeon introducing a narrow blunt-pointed knife to divide the stricture, after having brought the bowel into view, by a careful incision through the superjacent parts.



In speaking of the morbid state of the stomach and bowels, we should not omit to mention the curious, but simple means, by which poisons are now easily withdrawn from the stomach. A gum-elastic tube, about the thickness of one's little finger, is passed down the throat into the stomach, and a brass pump which holds about half-a-pint, is attached to the end of it. Two or three pints of warm water are now thrown into the stomach, to dilute the matters there, and the whole contents are then easily withdrawn. The syringe can act either as a sucking or forcing pump, so that, with fresh supplies of water, the stomach may be thoroughly washed out.

MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter II.—Multiplication.

9. Our first notions of multiplication are derived from operations on whole numbers ; from these we are led to regard it as a short mode of repeating a quantity as many times as there are units in the multiplier. We have already found it necessary to extend this fundamental signification of the term, so as to include within it those cases in which the multiplier is a fraction, (Arithmetic, chap. vi. art. 7. vol. i. p. 231) ; and as the literal symbols used in algebra are necessarily general, denoting fractional quantities as well as whole numbers, we must understand our terms in the same enlarged sense. Thus, the direction to multiply a by b, does not necessarily imply the repetition of a, a certain number of times, for b, the multiplier, may be less than 1 ; it is simply a direction to form with the quantity represented by a, another quantity which shall have the same relation to a, that b has to 1. If b be formed by repetitions of 1 ; that is, supposing it to denote a whole number, then the product of a by b will be formed by repeating a as many times as 1 is repeated to form the number b ; and if b be formed of a certain number of equal parts of 1; that is, supposing it to be a proper fraction, then will the product of a by b be formed by taking the same parts of a. The word *times*, which we employ in multiplication, must thus be understood to signify either repetition or partition, of the multiplicand, according as the multiplier is greater or less than 1.

10. In arithmetic we have had frequent occasion to make use of the sign $\times$, to indicate that the quantities between which it was placed were to be multiplied together. In algebra we occasionally employ it for the same purpose: thus, $a \times b$ signifies, in an arithmetical sense, that the quantity a is to be multiplied by the number b ; and in an algebraic sense we call $a \times b$, the product of a by b. The same is also sometimes expressed by a point : thus, $a \cdot b$ is the same as $a \times b$. But, the multiplication of literal quantities is more simply expressed by writing the letters in succession in the form of a word : thus, ab has the same meaning as $a \times b$ and $a \cdot b$, and is more concise, and therefore usually adopted.

11. The quantity ab is therefore, in algebraic language called the product of the factors a, b ; and to multiply this product ab by another number c, we write abc, and this we call the product of the factors a, b, c. From this then we perceive that multiplication in algebra, like addition and subtraction, is merely an indication of the arithmetical operation which is to be performed upon the numbers represented by the literal quantities. Thus, supposing $a = 4$, $b = 5$, $c = 6$, then

$$ab = 4 \times 5 \text{ or } 20, \text{ and } abc = 4 \times 5 \times 6 \text{ or } 120.$$

From this, therefore, we may conclude generally, that the rule for the multiplication of simple algebraic quantities is the following :

Write the letters consecutively in the order which is most convenient, without the interposition of any sign; and use the sign $\times$ *between numerals. The alphabetical arrangement of the letters is usually preferred.*

Thus, $a \times b \times c \times d$ is written $abcd$, and, reciprocally, every expression, such as $a\ b\ c\ d$, formed of several letters written immediately in succession to one another, designates always the product of the numbers represented by these letters.

We made tacit use of this convention in Article ii., (p. 127,) when illustrating the manner of writing numerical coefficients, which, being factors of the literal quantities to which they are prefixed, are obviously comprised in this rule. Thus, $6abc$, indicates that the quantity abc is taken 6 times, and is, therefore, according to our definition, the product of the four factors, 6, a, b, c ; or of the two factors, 6 and abc.

12. To indicate a multiplication in which there are several simple products having coefficients, we might apply the rule given above without error.

Thus, $4\,ab \times 3\,cd \times 5\,mq$ might be written $4\,ab\,3\,cd\,5\,mq$.

But as multiplications may be made in any order without affecting the numerical result of the operation,* we profit by this circumstance to collect, for the sake of simplicity and symmetry of expression, all the numerical coefficients together by the arithmetical rule. Thus, instead of writing

$4\,ab\,3\,cd\,5\,mq$, we write $4 \cdot 3 \cdot 5\,abcdmq$, or $60\,abcdmq$,

which is more concise, and in every respect more convenient. It is, however, to be borne in mind, that this is only a conventional conveniency; and that the one form of expression is identical with the other in signification.

13. From this, then, we conclude, that if the quantities† to be multiplied have coefficients, these must be multiplied together as in common arithmetic, and that the literal product must be written consecutively, as directed in the rule, Art. 11. The following are examples:—

$$2\,ax \times 4\,bb \times 5\,ax = 2 \times 4 \times 5\,ax\,bb\,ax = 40\,aa\,bb\,xx$$
$$\tfrac{1}{2}px \times 2\,pq \times 7\,ax = \tfrac{1}{2} \times 2 \times 7\,px\,pq\,ax = 7\,app\,q\,xx$$
$$\tfrac{1}{3}pq \times 3\,p \times 3\,q = 3\,pp\,qq \qquad \tfrac{1}{7}xy \times \tfrac{3}{4}yz \times \tfrac{1}{3}xz = \tfrac{1}{28}xx\,yy\,zz$$
$$\tfrac{7}{8}an \times \tfrac{5}{7}mq \times \tfrac{3}{4}pr \times am = \tfrac{15}{32}aa\,mm\,n\,p\,q\,r.$$

14. The multiplication of complex quantities is resolvable into the same operation as that explained, as exemplified in arithmetic; when the quantities to be multiplied together consist of several parts, every part of the one must be multiplied by every part of the other, and the sum of all the partial products must be taken as the total product of the two quantities. In algebra, these partial products can be found by the rules given above; although, as we shall presently see, the process presents a peculiarity which is not found in the arithmetical operation.

Let it in the first place be required to multiply $a + b$ by c, that is, to find c times $a + b$.

Here the product of a by c is ac, and the product of b by c is bc; but the product of the sum of a and b by c, is manifestly the sum of the product ac and bc; that is $ac + bc$.

Hence‡ c times $(a + b) = c\,(a + b) = ac + bc$.

Again, let it be required to multiply $a - b$ by c; that is, to find c times $a - b$. The partial products as before are ac and bc; but since a is greater than $a - b$ by the quantity b, it is therefore clear that c times a; that is, ac, is greater than c times $a - b$, by the quantity bc; consequently, bc must be subtracted from ac, which gives $ac - bc$ for the product required.

Hence c times $(a - b) = c\,(a - b) = ac - bc$.

The same reasoning clearly applies whatever be the number of terms in the multiplicand. These two cases, therefore, furnish the following rule for the multiplication of a complex quantity, by a quantity of one term; namely, *Write the multiplier into every term of the multiplicand.* In the practical application of this rule, we commonly multiply from left to right. The following is an example:—

$$\begin{array}{ll} \text{Multiply} & ab + c - 2\,d + 3\,m - 4\,n - qx \\ \text{by} & 2\,z \\ \hline \text{Product} & 2\,abz + 2cz - 4\,dz + 6\,mz - 8\,nz - 2\,qxz. \end{array}$$

The following exemplify also the use of brackets in this rule.—

$$2\,ax\,(a + b - c + 1) = 2\,aax + 2\,abx - 2\,acx + 2\,ax$$
$$\tfrac{1}{2}xy\,(x - z) + z\,(1 - z) = \tfrac{1}{2}xxy - \tfrac{1}{2}xy + z - zz$$
$$ab\,(x - 1) - bc\,(1 - x) - cd\,(1 + x) =$$
$$abx - ab - bc + bcx - cd - cdx$$
$$m\ \{ n\,(a + b - c - d + 1) + pp \} =$$
$$amn + bmn - cmn - dmn + mn + mpp.$$

15. When the multiplier is composed of several terms, we have the following cases:—

I. Let it be required to multiply $a + b$ by $c + d$. Here $a + b$ is to be taken $c + d$ times, that is c times $+\,d$ times; now c times $a + b$, is $ac + bc$, and d times $a + b$, is $ad + bd$; but $c + d$ times $a + b$ must manifestly be the sum of these partial products; that is, $(ac + bc) + (ad + bd)$ which, taking away the brackets, becomes $ac + bc + ad + bd$.

2d. Let it be required to multiply $a - b$ by $c + d$. Here c times $a - b$ by c is $ac - bc$, and d times $a - b$, is $ad - bd$; and the sum of these products is $(ab - bc) + (ad - bd)$; that is, taking away the brackets, $ab - bc + ad - bd$.

From these and similar examples then, we conclude that *the multiplier being the sum of several terms, the total product sought is composed of the sum of the partial products of the multiplicand by every term of the multiplier.*

Suppose now that the multiplier contains a subtractive term, it is clear that the products formed by that term, must be taken with a contrary sign to that which they have by the preceding rule. Treating this condition as above, let us inquire,

II. What is the product of $a + b$ by $c - d$? This question is by definition the following: what is c times $(a + b) - d$ times $(a + b)$? Now c times $a + b$ is $ac + bc$, and d times $a + b$, is $ad + bd$; consequently,

$$c \text{ times } (a + b) - d \text{ times } (a + b) = (ac + bc) - (ad + bd)$$
$$\text{that is } (c - d) \text{ times } (a + b) = (ac + bc) - (ad + bd)$$
$$\text{or } (a + b) \times (c - d) = ac + bc - ad - bd,$$

and this last is therefore the product sought, with the brackets struck out.

2d. What is $a - b$ multiplied by $c - d$? The answer to this question must obviously depend upon the same reasoning as that employed in finding the answer to that preceding. We have in the first place—

$$c \text{ times } (a - b) - d \text{ times } (a - b) = (ac - bc) - (ad - bd)$$
$$\text{that is, } (a - b) \times (c - d = ac - bc - ad + bd$$

by taking away the brackets of the product.

From these two, and other like examples, we conclude, that *when a term of a multiplier is preceded by the sign —, every partial product formed by that term will have the contrary sign to that of the corresponding term of the multiplicand.*

16. The preceding operations and the rules to which they lead, are directly deducible from the principles exemplified in Art. 14.

Thus putting $c + d = m$; then $(a + b) \times (c + d)$ becomes $(a + b)\,m = am + bm$; and putting for m its value we have

$$am + bm = a\,(c + d) + b\,(c + d) = ac + ad + bc + bd$$

Again putting $c - d = n$: then $(a - b) \times (c - d)$ becomes $(a - b)\,n = an - bn$; and putting for n its value we have

$$an - bn = a\,(c - d) - b\,(c - d) = ac - ad - bc + bd.$$

17. The multiplication of all complex quantities may be reduced to this last case by representing the sum of the positive terms in each of the two factors by a and c respectively, and that of the negative terms similarly by b and d; it then only remains to assign the values of the partial products ac, bc, ad, bd.

To render this plain, suppose that it is required to multiply $5\,x - 3\,y + 2\,z$ by $xy - 2\,z$. The multiplicand may obviously be written $(5\,x + 2\,z) - 3\,y$: let $5\,x + 2\,z = a$ and $3\,y = b$ then $5\,x - 3\,y + 2\,z = a - b$; similarly put $xy = c$ and $2\,z = d$; then $xy - 2\,z = c - d$. The product of $a - b$ by $c - d$ is

$$ac - ad - bc + bd$$

$$\text{but } ac = (5\,x + 2\,z) \times xy = 5\,xx\,y + 2\,xy\,z$$
$$ad = (5\,x + 2\,z) \times 2\,z = 10\,xz + 4\,zz$$
$$bc = 3\,y \times xy = 3\,xyy \qquad \text{and } bd = 3\,y \times 2\,z = 6\,yz$$
$$\therefore ac - ad - bc + bd = 5\,xxy + 2\,xyz - (10\,xz + 4\,zz) - 3\,xyy + 6\,yz$$
$$= 5\,xxy + 2\,xyz - 10\,xz - 4zz - 3\,xyy + 6\,yz$$

which is the product of $5\,x - 3\,y + 2\,z$ by $xy - 2\,z$.

18. Observing the results obtained in these cases, we find that

* It must be observed that this proposition is here assumed, not proved; and we may remark, that although so simple as almost to be thought self-evident, no faultless demonstration of it has yet been given. The following is an instance, $ab = ba$ for $a \times 1 = 1 \times a$; that is, a taken 1 time is the same as 1 taken a times; but $a \times b$, is b times as great as $a \times 1$, and $b \times a$ is also b times as great as $1 \times a$, which is the same as $a \times 1$; therefore $ab = ba$. This proof may be extended to

$$abc = cba = cab = bca = bac.$$

† By quantities we understand such magnitudes as can be represented by numbers; we may therefore without impropriety speak of their multiplication and division, bearing in mind, however, that a multiplier is always an abstract (never a concrete) number: the multiplier is the answer to the question, How many times?

‡ A quantity written before or after a quantity placed within brackets, is to be multiplied into every term of the enclosed quantity.

duced to nothing, being directed to the exact centre of motion at S; but at C, or at any other position of the pole in the circumference, between B and a point in the circle at the right side of the line W N, equidistant from H, in the segment of the circle adjacent to W, the force producing rotation will be proportional to the cosine of the angle formed between the line connecting the north pole of the needle with W, and the needle itself. In other words, it will be proportional to a line drawn from the centre of motion S, parallel to the line connecting the north pole with W, until it meets another line which is a continuation of the tangent to the circle of which the connecting line is a radius, and to which that tangential line is perpendicular. This parallel line which in the figure is represented by S C, when the pole is at C, may be considered in the light of a lever acting upon the needle at C, and drawing it towards N, and as the length of the lever, or—which is the same thing—of the line connecting the pole with the conducting wire, increases as the pole moves from the neutral point B, until it reaches N; and after passing N, diminishes until it reaches the other neutral point D, so does the tangential force upon the pole of the needle increase or diminish in a like proportion.

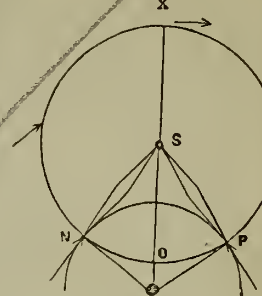
26. When the pole reaches the neutral point D, it is then said to be in equilibrium, and that equilibrium is stable; for if the pole be forced onward to E, the lever will then be within the smaller segment of the circle, which it will be perceived is divided into unequal portions by the two neutral points, and its tendency will be to drive the pole of the needle backward, or towards the neutral point D; the needle will therefore again fix itself at the neutral point, after a few oscillations.

27. If the needle be advanced farther in the direction of the point H, the force of the lever impelling it in a contrary direction, will increase until that point is attained, at which the needle points directly towards the conducting wire; but if it be carried beyond that point, the contrary force diminishes gradually, until the neutral point on the left side is reached, where the needle is again in equilibrium; but, in this case, an unstable equilibrium; for, if the needle be made to oscillate ever so little, its tendency will be to pass the neutral point, and move onward with increasing rotatory force until it reaches N, and with diminishing rotatory force afterwards, until the position of stable equilibrium is once more attained at D.

28. It has been already observed that the needle is urged in opposite directions in different parts of the circle; that, in the northern or remote portion, its tendency is onward from west to north, and north to east; but in the adjacent or southern portion, the tendency is from west to south, and south to east; but inasmuch as at the neutral point on the left, the tangential force is in a direct line with the needle itself, which is therefore at right angles to the line connecting its pole with the conducting wire, this force, so acting, gives the needle a forward impulse, exceeding the contrary impulse to which the needle would be subject, if its pole lay on the southern side of the neutral point, and in consequence it is carried round the *larger* arc, in place of the *smaller*, in its endeavour to reach its position of stable equilibrium;—thus, that preference for the *circuitous*, in place of the *nearer* path to its destination, which appeared so marvellous and inexplicable to the earlier observers, must now appear, to the attentive reader, only a natural consequence of the tangential direction in which the electro-magnetic influence operates.

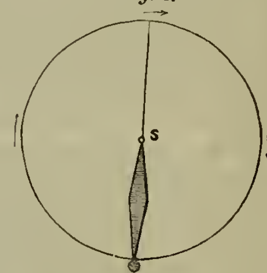
29. When the conducting wire is placed very near the circle round which the pole of the needle moves, the disproportion between the unequal portions of the circle is considerably augmented, and becomes still greater, the nearer the wire is approached to the circle; thus, in figure 7, the arc N, O, P, is extremely small compared with the larger arc N, X, P; but if the needle be placed at the least possible distance from the line connecting the centre of motion with the conducting wire, and upon the left side, in place of passing over the diminished arc to attain the point, P, of stable equilibrium, it will instantly recede from that point and move in the opposite direction, as if repelled, until by the circuitous route it reaches the point of permanent neutrality.

Fig. 7.



30. If we suppose the conducting wire to pass through the circumference itself, in such case, the arc which in the former case separated the two neutral points is reduced to nothing, and therefore if the needle be placed on the left of the wire, but nearly in contact with it, as in figure 8; it will move all round the circle, until it reaches the other side of the wire; but then, its position will be unstable; for, the impetus it has already received will suffice to carry it past this point, and then it, of course, receives a fresh impulse, so that it may be assumed to be capable of maintaining a state of continued revolution. If the conducting wire be placed *within* the circle, the neutral points have, in such case, no existence, and under such circumstances, the needle would perpetually revolve in the same direction, if the substance conducting the current were of such a nature as to admit of the passage of the needle across it.

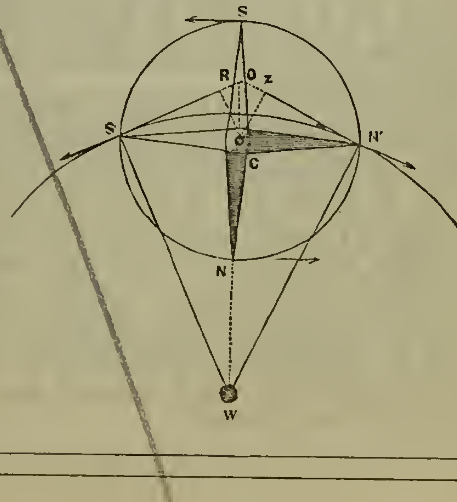
Fig. 8.



31. It may be here observed, that when the arcs of oscillation of the needle are small, the influences which tend to bring the needle to its point of rest bear a very near proportion to the arcs themselves; so that the motions of the needle in this respect depend upon the same law as those of the pendulum; for which reason they are available in estimating the comparative intensities of the electro-magnetic influences when acting on the needle at different distances, and with greater or less quantity of current; for the force will be found to be strictly proportional to the square of the number of oscillations performed by the needle in a given time.

32. We are now in a position to comprehend with greater facility the combined action of an electric current upon *both* poles of a magnetic needle, balanced in the usual way upon its centre, and we shall first take the case of a current moving downward in a vertical wire *external* to the circle in which a horizontal magnet moves. If N S, figure 9, repre-

Fig. 9.



sent a needle having its north pole pointing towards the conducting wire, W, as soon as the downward current is sent through that wire, the needle will assume a new position, S′ N′, at right angles to its former one, and *there* it will attain a state of stable equilibrium; for when it reaches that position, each pole will be influenced by a force at the *same* side of the magnet's axis, C, and the forces so acting will be equal, and possess the same mechanical advantage, inasmuch as the poles are equidistant from the conducting wire. In other words, the tangential forces being directed at right angles towards W S and W N, as shown by the arrows, oppose one another, and acting by the levers, R C and Z C, which are equal in length, are in exact equilibrium, which must be stable, for this reason, that the displacement of S′ in a northerly direction will lengthen the lever on that side, as already explained; while it will shorten the lever, R C, on the other side. The power of the longer lever will therefore preponderate, and the needle will be carried back to its former position. In like manner, if the pole, S′, were moved in a southerly direction, the force which impels the pole, N′, would in that case have the advantage acquired by the longer lever; and its effect would be to bring back the needle to its rectangular position.

33. If, under similar circumstances, the centre of the needle were unrestrained by the pivot supporting it, the resultant of the equal and contrary forces which established the needle in a position of stable equilibrium, passing through the centre of motion, C, would, of course, have no tendency to produce rotation; but when applied at the point, O, (fig. 9,) would tend to draw the conducting wire and the centre of the magnet towards each other; but if the wire were placed at the contrary side, the tangential forces would then be *towards*, instead of *from*, each other, and, in consequence, produce a resultant which would tend to draw the magnet and wire directly *from* one another, and thus produce an appearance of repulsion.

ANATOMY AND PHYSIOLOGY.

CHAPTER XX.

SECRETION AND EXCRETION.

THE process by which new compounds are formed from the blood is called *secretion*. Some of these products are of use in the system, as the bile and the saliva; others are excrementitious, or intended to be discharged from it, as the sweat and the urine, and are hurtful if retained. These latter are technically distinguished as *excretions*. The two classes are not, however, strictly separable, as some substances require to be separated as excretions, and yet are made useful in their passage through the body. Thus, the bile contains a great deal of charcoal which requires to be separated from the blood; yet it is not merely poured into the intestines to be discharged, but, in mixing with the food, it produces a chemical change, as noticed in the last chapter, and causes the separation of the milky chyle, which is then presented to the mouths of the absorbents.

The secretions which serve for moistening membranes are the *mucus*, for the mucous membrane of the lungs and digestive organs; the *serum*, for the serous membranes of the chest, belly, and head; the *synovial fluid*, for the joints; the *tears*, for keeping the eye wet; and the *sebaceous* matter, as it is called, a waxy yellowish substance which is seen at the edges of the eyelids, and gives the whole surface of the body an oily appearance, when not removed by frequent washing. Those which assist in digestion are the *saliva*, the *gastric fluid*, the *pancreatic juice*, and the *bile*. There is one which is formed only at particular times—the *milk*, furnished by the mother for the nourishment of her offspring. Those which are purely excrementitious, are the *urine* and the *sweat*. Let us now examine each of them in succession, along with the apparatus in which it is formed.

Many of these fluids are prepared, without the aid of any peculiar structure which we can detect; all that we can ascertain being, that the arteries run in great profusion upon a membrane, and divide to great minuteness; and that in proportion as blood arrives at the membrane, the new fluid is produced. Others are formed in a peculiar apparatus called a *gland*, where the arteries appear to undergo a change in their own nature, and to have the power of changing the nature of their contents. In speaking of the blood, it was already remarked, that at the present day it is generally believed that the materials of all the secretions exist in it, and that the glands merely separate them from the mass of the circulating fluid. The process of secretion undoubtedly goes on under the influence of the nerves; for we find nerves distributed to all the secreting organs; and when these nerves are destroyed or injured, secretion ceases to go forward. As it depends on the presence of blood and of nervous energy, it is plainly a vital process.

The mucous and serous membranes, with their secretions, have been already spoken of in the chapters on the lungs, p. 549 of the first volume, and the digestive apparatus, p. 94 of the present one. It is only necessary here to state their chemical composition.*

The next secretion, mentioned two paragraphs back, was that of the *synovia*. This fluid, which serves for oil to the joints, and which feels very like oil between the fingers, nevertheless contains no oil, but is of a mucilaginous nature.† The synovial membrane is formed like a serous one, being a shut bag, whose surfaces are everywhere in contact; yet the surface of the membrane itself is like the mucous one lining the mouth and throat, being soft and velvety. It seems linked by a closer sympathy to the serous than to the mucous membranes, for we find the serous membranes to *sympathize* with inflamed synovial membranes; that is to say, when a joint is sorely inflamed, it is not uncommon for the serous membrane lining the belly or chest, or covering the heart, to become inflamed too, without any other cause that we can discover, than what we call the *sympathy* depending on the similarity of structure. A plan of a synovial membrane is given in vol. i., at p. 365.

All the other secretions are formed from the blood by means of peculiar *glands* which are set apart for the purpose. These differ from one another in form and structure; and yet we can see nothing in any one of them which can explain to us why its peculiar secretion is formed in *it*, and not in every other. The old physiologists fancied that each gland was like a strainer, pierced with holes of a particular size and form, so that substances of one kind passed through from the blood in one gland, but were retained in another, where something else was permitted to pass. This, however, is too mechanical an explanation. It has been already said, that the process seems to be under the regulation of the nervous influence.

Every gland consists of a congeries of small particles, from the size of a pin-head down to that of a grain of sand, each of which may justly be regarded as a perfect gland, complete in itself. For each of these particles, (represented here as greatly magnified,) will have an artery, *a*, carrying blood to it, both for its nourishment, and for the material of secre-

* MUCUS.

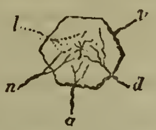
Water,	933·7
Mucus,	53·3
Chlorides of potassium and sodium,	5·6
Lactate of soda, with animal matter,	3·
Soda,	0·9
Albumen and animal matter, soluble in water, with phosphate of soda,	3·5
	1000·

SERUM.

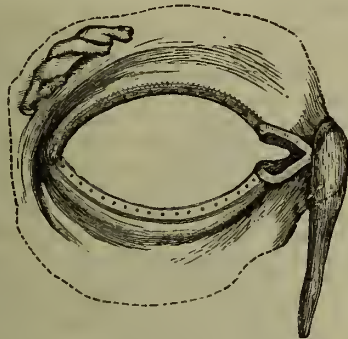
Chlorides of sodium and potassium,	6·60
Carbonate of soda,	1·65
Sulphate of potash,	0·35
Phosphate of lime, with traces of magnesia.	0·60
Mucous extractive matter,	4·
Albumen,	86·8
Water,	900·
	1000·

† It is said to contain albumen, fatty matter, an animal substance soluble in water, soda, chloride of sodium and potassium, phosphate and carbonate of lime.

tion; a nerve, *n*, directing the process; a duct *d*, conveying away the product; a vein *v*, receiving the superfluous blood; and a lymphatic *l*, as every other part of the body has, for removing that part of the structure which is hourly becoming incapable of performing its functions aright. The liver is the gland on which we have been able to make the most accurate observations, as being the largest, and the most distinct in its structure, but there can be no doubt that the others are arranged much on the same principle. The blood from which the secretion is to be made is distributed to the outside of the granule which we examine; the vein passes off from the centre of the granule; and it is while the blood is passing from the outside to the centre, that, under the influence of the nerves, the separation of the new product is accomplished.



The *tears* are poured out by the *lachrymal gland*, situated in the upper and outer part of the orbit, or cavity for the eye, where it is protected from external violence, being completely within the bony rim, which is indicated in the accompanying sketch by a dotted line. It is about the size of a tamarind stone, and convex on its upper surface, so as to suit the concavity of the roof of the orbit. It consists of a multitude of yellow granules, bound together by cellular tissue, and to it are distributed the blood of a small artery and the branches of a small nerve. From this gland run from five to seven small ducts, (not represented in the figure) which convey the tears from it, perforate the mucous membrane at the outer part of the orbit, and so let the tears wash the whole surfaces of the eye and eyelids, before they escape into the nose at the inner angle. The secretion of tears is constantly going on, but in small quantity, merely for the purpose of keeping the eye moist. When any irritating substance alights upon the eye, or gets inside the eyelids,—as a particle of dust or an insect,—an increased flow of tears is immediately excited, in order to wash it away. This sudden flow, it need scarcely be remarked, is also brought on by mental emotion. A little red projection is seen between the eyelids at their inner angles, being a rudiment of the *haw* or third eyelid, which we see in all birds, and in some beasts, as the horse and cow. Its use in man is to prevent the tears from running out upon the cheek. At the projecting angle which each eyelid forms, just before its inner termination, if it be everted a little, a small hole will be seen, for the absorption of the tears. Along the two canals seen in the figure leading from these holes, the tears pass into a duct, rather larger than a crow-quill, which lies underneath the little knot which is felt on the side of the root of the nose, at the inner junction of the eyelids. This duct terminates in the nose, and conveys the tears there, after they have done all that is expected of them above. This is the reason why you blow your nose strongly, and close your eye, when any particle of dust has lodged in it, with the view of getting it drawn toward the inner angle (where it lodges, and whence it can be wiped out), by the tears which are passing into the nose through the lachrymal canals. In a dusty day, an accumulation of particles is seen in the recess beside the little red projection, ready to be wiped away.*



It is an extremely rare thing for any disease to attack the lachrymal gland; the author has, however, seen a case where it became enlarged and hard, and could be distinctly felt from the outside. On the other hand, the excreting lachrymal organs are very apt to go wrong. The duct often inflames, so that the tears cannot get down it, and run over the cheek, producing troublesome excoriations. Sometimes it suppurates and bursts; and then it requires a bit of silver wire to be introduced, and to be worn in it for some time, to keep open the passage into the nose, which has a tendency to become obliterated.

The whole *skin* is thickly covered with the orifices of minute bags, which excrete an oily matter, to keep it soft and pliant. These are more numerous in some parts than others, as in the arm-pits, and produce a disagreeable heavy effluvium, if care be not taken to keep the skin perfectly clean. This smell is particularly strong in people of colour. On the face, the orifices of these ducts are apt to become obstructed, and present little black points, projecting slightly above the level of the skin. When these are squeezed, the retained waxy matter is evacuated, assuming the shape of a little worm, from being forced through the narrow aperture. Frequently the irritation becomes greater, and a little pus forms, causing a pimple. Nothing that we know of is efficacious in keeping them back, notwithstanding all that the venders of lotions say to the contrary. Strict attention to cleanliness is the main thing; and the little points must be squeezed out daily as they appear. It is, however, the case, that in persons of intemperate habits, these spots increase and multiply to a very disagreeable extent.

In the *eyelids*, those little glands are collected into two sets, and on looking at their edges, twenty or thirty small holes will be seen in each, whence a yellow matter exudes. (In the last figure, these are seen forming the row of distinct holes; the row of still smaller ones, closely ranged together, being the apertures in which the eyelashes were set.) After cold, this matter is apt to become increased in quantity so as to glue the eyelids together in the morning, and to remain sticking in little yellow bits, while the edges of the lids themselves become inflamed. In such cases, the first rule to be attended to is, that the eyelids must not be forcibly separated, or else some of the adhering eyelashes will be pulled out; but the matter must first be softened with a rag and warm water. At night, a little eye-salve must be regularly put between the lids; and in those who are subject to this annoyance, (although they be not ill with it,) the ointment should be used at least once a-week, as a preventive measure. In scrofulous children who are ill taken care of, we often see this complaint go a shocking length, destroying all the eyelashes, causing little ulcers, and ending by rendering the edges of the lids smooth, hard, and rounded, instead of possessing their natural delicacy of structure.

The *salivary glands* have been already noticed in speaking of the mouth. There are three on each side, the *parotid* beside the ear, the *sublingual* under the tongue, and the *submaxillary* under the angle of the jaw. The saliva flows from them in great quantity during mastication, in consequence of the pressure which they undergo. Nervous feeling, or even mental emotion, has something to do with it, however; for the saliva flows from a hungry person on even seeing a piece of meat; so that there is truth in the common phrase, which describes an eager person's mouth as watering.*

The *gastric juice* has been already sufficiently treated of, under the head of digestion, p. 94. Its chemical composition is by no means satisfactorily ascertained.

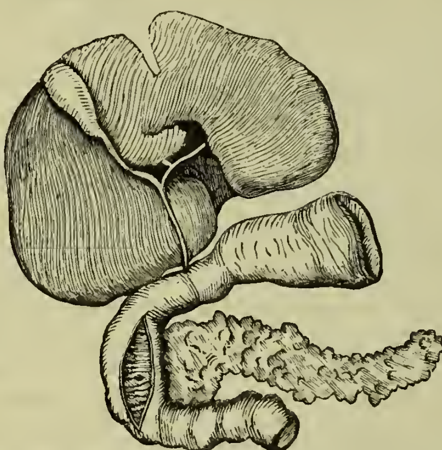
The *pancreas* is identical in structure with the salivary

* The substances found in tears by Fourcroy and Vauquelin are, water, mucus, common salt, soda, phosphate of lime, phosphate of soda.

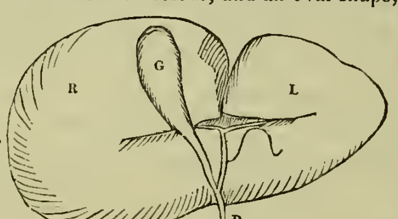
* The quantity secreted in twenty-four hours is about 7½ ounces avoirdupois. The chemical composition of the saliva, as determined by Berzelius, is—

Water	992·9
Salivin	2·9
Mucus	1·4
Alkaline chlorides	1·7
Lactate of soda, with animal matter	0·9
Soda	0·9
	1000·7

glands communicating with the mouth, so that it has been called the abdominal salivary gland. It is in shape like a dog's tongue, and lies across the spine, below the stomach, and nearly surrounded by the first part of the small intestine, into which its duct perforates, close to, or along with, the entry of the one from the liver.



The *liver* is the largest gland in the body, weighing in general, from four to five pounds. It lies in the right side, close under the diaphragm, and over the stomach. It is connected by folds of the peritonæum, or lining membrane of the belly, to the neighbouring parts, these folds being called its ligaments. It is of a reddish colour, and an oval shape, its greater end being to the right, and its smaller one to the left; its convex surface directed upward to the concavity of the diaphragm, and its concave surface downward to the stomach. If examined on the surface, or by cutting a slice out of it, it appears all mottled, consisting of an infinity of little grains, each of which may be considered as a perfect gland. Each grain receives a twig from a great vein, which brings to the liver the blood which has been circulating through the rest of the belly, and each gives off a twig to the biliary ducts. The secretion in the liver differs from that in other glands, in this, that it is not from *arterial*, but from *venous* blood. The reason of this seems to be, that as bile consists in a great measure of carbon, more of the material is furnished by the venous blood. In consequence of this, a considerable share of the duty of purifying the venous blood, by taking away its carbon, is performed by the liver, and only a part of the business is left to be completed by the lungs, as described in the chapter on respiration, p. 616 of last volume.*



The liver receives a large artery for its nourishment, and branches of nerves go to it, to enable it to perform its functions. The gall-duct D, runs from the liver to the small intestine, (which is slit open, in the preceding figure, to show the aperture common to it and the pancreatic duct,) allowing the bile to combine with the food, and produce a chemical change upon it. The flow of bile is always greatest at the time when the food is passing through the bowels. At other times, it passes by a side duct into the gall-bladder G, where it is reserved till it be wanted. The figure represents the under surface of the liver; R being the right or larger lobe, and L the smaller or left.

The liver is very little subject to disease in this climate. Those persons who are said to be bilious, are so in consequence of derangement of their stomach. In hot climates, as in India, the liver is very liable to inflammation, and sometimes matter forms in it, and bursts externally. Any irritation of the liver is apt to produce jaundice, (French *jaune*, yellow,) which is just the absorption of the bile into the circulation, so that its yellow tint predominates over the red colour of the blood. The liver is also occasionally subject to general enlargement, and to a firm condensation, occasioning dropsy, principally in persons of intemperate habits; and cancerous growths now and then form in it, which can sometimes be felt by laying the hand upon the outside.

The *female breast* will be described in the article on reproduction.

The excrementitious secretions, or *excretions*, are the *urine* and the *perspiration*. These are exceedingly similar to one another in their nature, and are to a certain extent vicarious; that is, the one is able so far to supply the place of the other. Thus in winter, the perspiration is mostly suppressed, and the calls to make water are much more frequent than in summer, when the reverse is observed. Also, in those diseases of the kidneys, where no urine, or almost none is formed, the sweat becomes copious, and of a horribly offensive odour, which indicates that the salts of the blood which should pass off by the kidneys, are escaping by the way of the skin.*

No particular apparatus can be detected, having for its object the formation of the perspiration. Over the surface of the skin are scattered an infinity of holes, through which the hairs pass; and it would seem that the perspiratory ducts open into these, before they arrive at the surface.

Perspiration is constantly going on, although we may not be aware of it, and this is called the insensible perspiration. Every one knows that he perspires, and that if the perspiration be checked, as by a cold draught of air, the effect is hurtful, but few know the extent of the function which is interfered with. Lavoisier and Seguin made a series of experiments on this subject. The experimenter enclosed himself in a silk varnished bag, up to the mouth, and had himself and the bag weighed, at the commencement of the experiment. Then, at its termination, he was weighed again, still remaining in the bag. The loss of weight, of course, was lost by breathing, being the carbon and vapour which had disappeared—see vol. i., p. 616. Lastly, coming out of the bag, he was weighed a third time, the loss this time, being the loss by perspiration. Of course the experimenter attended minutely to the quantity of food and drink which he swallowed, and made the requisite allowances. The result was, that the medium loss by the skin, in a day, is 32 oz. Be it remembered, that this is what we style the *insensible* perspiration. The *sensible* or *visible* sweat will come off in much greater quantity in a much shorter time. A strong man, acting as a glass-blower, will lose from 3lb. to 4lb. in an hour. There is no wonder that these work-people should be so given to drinking;—although we may certainly regret that their habitual drink should be so strong.

This perspiration, it has been said, is constantly going on. In *dry* weather it is not observed, because it evaporates immediately. In *damp* weather, it stands upon one's brow in drops, because it does not get evaporated. In *hot* weather, it wets one all over, because much more of it is poured out, for the purpose of keeping down the heat, which would otherwise be insupportable. It is in imitation of this natural

* The bile contains, according to Berzelius,—

Water,	904·4
Biliary matter and fat,	80·
Mucus of gall-bladder,	3·
Extract of meat, common salt, lactate of soda,	7·4
Soda,	4·1
Phosphates of soda and lime, and substances insoluble in alcohol	1·1
	1000·

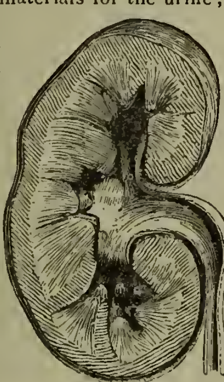
* Dr. Thomson says that it contains the lactates of soda, potash, lime, and magnesia, together with common salt, sal-ammoniac, and traces of chloride of potassium, phosphate of soda, and phosphate of lime; also animal matter, insoluble in alcohol.

process, that we give a sweating powder to a man labouring under a fever; he sweats all night, and in the morning he is found cooler, and the fever has in a great measure left him.

The application of cold chills the surface, represses the cutaneous exhalation, and drives the blood inward, in too great quantity, upon the lungs, or some other weak part, which is apt to suffer. This is what is meant by *taking cold.* It is no wonder that serious consequences should ensue, where 2500 square inches, (for that is the superficial extent of the skin) have their secretion repressed, and the blood that should furnish it, driven in upon the internal organs. Consequently, to relieve the feeling of this *taking cold,* the plain way is to bring back heat to the skin;—to bathe the feet, or take a general hot bath, to swallow a hot gruel, or a sweating powder; and on turning-in to bed, to put on an additional blanket.

From what has been said of the quantity of matter which passes through the skin, it will be plain of what importance cleanliness is. To maintain this, the body should be spunged every day from head to foot, and rubbed dry with a coarse towel.

The *kidneys* are two in number, situated in the belly, one on each side of the spine. Each kidney is of an oval shape, with a notch in the side next the spine. Into this notch the vessels enter. A large artery furnishes the materials for the urine; a duct conveys it away when formed; and a vein removes the superfluous blood. In the figure, one-half of a kidney is shown, cut perpendicularly through the middle, so as to show its internal structure. From eight to fourteen cones are seen, consisting mostly of straight vessels, projecting from that part of the organ to which the blood is most profusely distributed, from whose points the urine distils, drop by drop, into three membranous funnels. These three funnels unite in the great bag of the kidney, from which the pipe called the *ureter* leads down to the bladder. The bladder is seated in the fore part of the cavity at the lower part of the belly called the *pelvis;* it has two openings behind, for the two ureters, perforating very obliquely, so as to prevent regurgitation. From its front and lower part, the *urethra* or water-pipe passes out, through which the urine is to be expelled from the body.



The *urine* is a highly animalized fluid, as might at once be supposed from the rapidity with which it passes into putrefaction. It appears to contain a great deal of the waste, or worn-out parts of the body, particularly the saline particles. These salts consist of potash and soda, ammonia, (commonly called hartshorn) which gives it its pungent smell, and a substance called *urea,* on which many of its peculiarities depend. In disease, the urine is affected in various ways. Sometimes its quantity is increased or diminished. In the healthy state, a full-grown man voids nearly three pints of urine in a day, the quantity varying in an inverse proportion to the perspiration, and in direct proportion to the drink taken, and to individual peculiarities. In dropsy, the quantity is reduced to one or two wine-glassfuls; and in a very curious disease called *diabetes,* it is sometimes increased to so much as thirty pints. It varies also in its qualities. In the last-mentioned disease, it becomes sweet, its salts are changed into sugar, which may be crystallized from it, pure and white. Its salts may also become too great in quantity for the water to dissolve, and then they fall down to the bottom of the bladder, and constitute a sediment, which sometimes concretes into stones. When stones are once formed in the bladder, they produce dreadful irritation, and require to be removed by an operation. Stone has long been a capital subject for quacks, who sell medicines which they pretend can dissolve it while in the bladder. All this, however, is mere pretension; for anything strong enough to dissolve the stone, would first destroy the coats of the bladder. Their medicines, in general, contain soda, which passes into the urine, and has the effect of coating over the stone, and so rendering it for the time less irritating, but lays the foundation for still greater suffering, by increasing its bulk. Nothing indeed can be trusted for a cure, but the removal of the offending body, by the surgical operation of lithotomy.*

DESCRIPTION OF THE TITHONOMETER,

AN INSTRUMENT FOR MEASURING THE CHEMICAL FORCE OF THE INDIGO-TITHONIC RAYS.†

By John W. Draper, M.D.,

Professor of Chemistry in the University of New York.

I have invented an instrument for measuring the chemical force of the tithonic rays which are found at a maximum in the indigo space, and which from that point gradually fade away to each end of the spectrum. The sensitiveness, speed of action, and exactitude of this instrument, will bring it to rank as a means of physicial research with the thermo-multiplier of M. Melloni.

The means which have hitherto been found available in optics for measuring intensities of light, by a relative illumination of spaces or contrast of shadows, are admitted to be inexact. The great desideratum in that science is a photometer, which can mark down effects by movements over a graduated scale. With those optical contrivances may be classed the methods hitherto adopted for determining the force of the tithonic rays by stains on Daguerrotype plates, or the darkening of sensitive papers. As deductions drawn in this way depend on the *opinion* of the observer, they can never be perfectly satisfactory, nor bear any comparison with thermometric results.

Impressed with the importance of possessing for the study of the properties of the tithonic rays some means of accurate measurement, I have resorted in vain to many contrivances; and, after much labour, have obtained at last the instrument which it is the object of this paper to describe.

The tithonometer consists essentially of a mixture of equal measures of chlorine and hydrogen gases, evolved from, and confined by, a fluid which absorbs neither. This mixture is kept in

* Dr. Thomson, in his *Animal Chemistry,* gives the following analysis of urine:—

Urate of ammonia,	0·298
Sal-ammonia,	0·459
Sulphate of potash,	2·112
Chloride of potassium,	3·674
Chloride of sodium,	15.060
Phosphate of soda,	4·267
Phosphate of lime,	0·209
Acetate of soda,	2·770
Urea, with colouring matter,	23·640
	52·489
Water, with a free acid, probably the lactic,	947·511
	1000·

† It may be necessary to remind the reader, that in analyzing the solar beam, all parts of it are not found equally active in producing chemical effects; the conclusion, indeed, now very generally admitted by those who have investigated the subject closely is, that in the solar beam there are three distinct kinds of rays—namely, those possessing heating properties, which are termed the *calorific* rays; those producing the sensation of light, and which we called the *luminous* rays; and, lastly, those producing chemical effects, as exemplified in photogenic processes, and the union of chlorine and hydrogen when exposed in mixture to the sun's light; and which Dr. Draper proposes to call *tithonic* rays. In this he adopts the idea of peculiar matters of light and heat, and considers that the chemical effects are produced by a peculiar material agent, which he terms *Tithonicity.* *Actinism* is the term more generally used, and is less liable to objection, as explained in our first chapter on Photography. The name applied by Dr. Draper may hereafter be found inappropriate, and it does not appear to be in the meantime absolutely needed; but the researches with which it is connected are highly valuable, and the instrument described in the following paper will undoubtedly, either in its present or some modified form, be found invaluable in future investigations respecting the chemical properties of light.

a graduated tube, so arranged that the gaseous surface exposed to the rays never varies in extent, notwithstanding the contraction which may be going on in its volume, and the muriatic acid resulting from its union is removed by rapid absorption.

The theoretical conditions of the instrument are therefore sufficiently simple ; but, when we come to put them into practice, obstacles which appear at first sight insurmountable are met with. The means of obtaining chlorine are all troublesome; no liquid is known which will perfectly confine it ; it is a matter of great difficulty to mix it in the true proportion with hydrogen, and have no excess of either. Nor is it at all an easy affair to obtain pure hydrogen speedily, and both these gases diffuse with rapidity through water into air.

Without dwelling further on the long catalogue of difficulties which is thus to be encountered, I shall first give an account of the instrument in the form I now use it, which will show to what an extent all those difficulties are already overcome.

Description of the instrument. First, of the glass part.—The tithonometer consists of a glass tube bent into the form of a siphon, in which chlorine and hydrogen can be evolved from muriatic acid, containing chlorine in solution, by the agency of a voltaic current. It is represented by fig. 1, where *a b c* is a

Fig. 1.

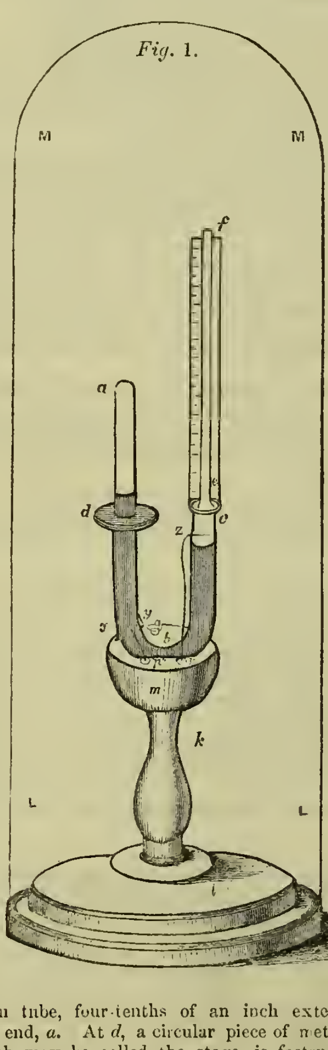


Fig. 3.

Fig. 2.

clear and thin tube, four-tenths of an inch external diameter, closed at the end, *a*. At *d*, a circular piece of metal, an inch in diameter, which may be called the stage, is fastened on the tube, the distance from *d* to *a* being 2·9 inches. At the point, *x*, which is two inches and a quarter from *d*, two platina wires, *x* and *y*, are fused into the glass, and entering into the interior of the tube, are destined to furnish the supply of chlorine and hydrogen; from the stage, *d*, to the point, *b*, the inner bend of the tube is 2·6 inches, and from that point to the top of the siphon *c*, the distance is three inches and a half. Through the glass at *z*, three quarters of an inch from *c*, a third platina wire is passed ; this wire terminates in the little mercury cup *r*, and *x* and *y* in the cups *p* and *q* respectively.

Things being thus arranged, the instrument is filled with its fluid, prepared, as will presently be described ; and as the legs *a b*, *b c*, are not parallel to each other, but include an angle of a few degrees, in the same way that Ure's eudiometer is arranged, there is no difficulty in transferring the liquid to the sealed leg. Enough is admitted to fill the sealed leg and the open one partially, leaving an empty space, to the top of the tube at *c*, of two and three quarter inches.

A stout tube, six inches long and one-tenth of an inch interior diameter, *e f*, is now fused on at *c*. Its lower end opens into the main siphon tube ; its upper end is turned over at *f*, and is narrowed to a fine termination, so as barely to admit a pin, but is not closed. This serves to keep out dust, and in case of a little acid passing out, it does not flow over the scale and deface the divisions. At the back of this tube a scale is placed, divided into tenths of an inch, being numbered from above downward. Fifty of these divisions are as many as will be required. Fig. 2 shows the termination of the narrow tube bent over the scale.

From a point one-fourth of an inch above the stage *d*, downwards beyond the bend, and to within half an inch of the wire *z*, the whole tube is carefully painted with India ink so as to allow no light to pass ; but all the space, from a fourth of an inch above the stage *d*, to the top of the tube *a*, is kept as clear and transparent as possible. This portion constitutes the sentient part of the instrument. A light metallic or pasteboard cap, A D, fig. 3, closed at the top and open at the bottom, three inches long and six-tenths of an inch in diameter, blackened on its interior, may be dropped over this sentient tube ; it being the office of the stage *d* to receive the lower end of the cap when it is dropped on the tube so as to shut out the light.

The foot of the instrument, *k l*, is of brass, it screws into the hemispherical block *m*, which may be made of hard wood or ivory ; in this three holes, *p q r*, are made to serve as mercury cups ; they should be deep and of small diameter, that the metal may not flow out when it inclines for the purpose of transferring. A brass cylindrical cover L M, L M, may be put over the whole ; when it is desirable to preserve it in total darkness, it should be blackened without.

Secondly, of the Fluid Part.—The fluid from which the mixture of chlorine and hydrogen is evolved, and by which it is confined, is yellow commercial muriatic acid, holding such a quantity of chlorine in solution that it exerts no action on the mixed gases as they are produced. From the mode of its preparation it always contains a certain quantity of chloride of platina, which gives it a deep golden colour, a condition of considerable incidental importance.

When muriatic acid is decomposed by voltaic electricity its chlorine is not evolved, but is taken up in very large quantity and held in solution ; perhaps a bichloride of hydrogen results. If through such a solution hydrogen gas is passed in minute bubbles, it removes with it a certain proportion of the chlorine. From this therefore it is plain, that muriatic acid thus decomposed will not yield equal measures of chlorine and hydrogen unless it has been previously impregnated with a certain volume of the former gas. Nor is it possible to obtain that degree of saturation by voltaic action, no matter how long the electrolysis is continued, if the hydrogen is allowed to pass through the liquid.

Practically, therefore, to obtain the tithonometric liquid, we are obliged to decompose commercial muriatic acid in a glass vessel, the positive electrodes being at the bottom of the vessel and the negative at the surface of the liquid. Under these circumstances, the chlorine as it is disengaged is rapidly taken up, and the hydrogen being set free without its bubbles passing through the mass, the impregnation is carried to the point required.

Although this chlorinated muriatic acid cannot, of course, be kept in contact with the platina wires without acting on them, the action is much slower than might have been anticipated. I have examined the wires of tithonometers that had been in active use for four months, and could not perceive the platina sensibly destroyed. It is well, however, to put a piece of platina

ON THE INCIPIENT DISENGAGEMENT OF ELASTIC FLUIDS.

By John Thomas Woodhouse, M.D.

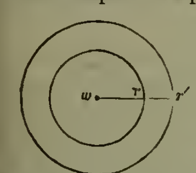
I have never seen or heard a satisfactory explanation of the well-known fact, that when a tea-kettle, with boiling water in it, is removed from the fire, the bottom is only moderately warm. It has been referred to like causes (substituting steam for vapour), as when spirits are thrown upon the skin, and a sensation of cold is produced, in which case heat is first given to the fluid, succeeded by a change in the state of the fluid.

This explanation appears to me defective and unsatisfactory; and I will now endeavour to show where it is defective, and supply the defect.

When the kettle boils, the water in it will raise the thermometer to 212° Fahrenheit; the fire is much hotter, and yet the hand which soon after touches it feels only a moderate warmth; in a short time the heat becomes intolerable—*i. e.*, of the same heat as the superincumbent fluid.

Now, admitting, when the heat of the bottom is becoming greater than 212°, that the water undergoes a change by its conversion into steam, and that the heat of the contents of the kettle is thus partly latent,—admitting that this would account for the bottom not indicating a greater heat than 212°, I contend it is unequal to explain why the bottom should be less than 212°: for the water is 212°, the steam under the ordinary pressure of the atmosphere is supposed to be 212°, and the fire which was under it more than 212°. The object of this paper is to explain why the bottom, immediately on its removal from the fire, should indicate a heat less than 212°, and soon after a heat equal to that of the water upon it.

Let w represent a portion of water. Let the sphere, whose radius is $w\ r$, represent the space occupied by the steam, into which this portion is converted by the communication of heat. The heat of the steam filling this sphere would be 212°; but, in explaining the object of this paper, I suggest that the heat of the steam may be less than 212°, and to establish this, I propose the following theory:—



I assume, that when a portion of water is converted from its fluid into its gaseous state, a sudden expansion, or what may be termed an explosion, happens; *i. e.*, supposing the steam in its quiescent state, and under the ordinary pressure of the atmosphere, would occupy the sphere, $w\ r$, at the instant of its conversion, by its elasticity or momentum of its particles, it proceeds to fill a sphere whose radius is $w\ r'$, which is greater than $w\ r$.

Now, according to the acknowledged doctrine of latent heat, when water receives heat which converts it into steam, the steam under atmospheric pressure would occupy a space varying with the quantity of caloric imparted to it. By the same doctrine of latent heat, if the same quantity of steam under the same pressure be made to occupy the greater space, $w\ r'$, it would require a greater quantity of caloric; and supposing the change from its filling the sphere, $w\ r$, to its filling the sphere, $w\ r'$, to be effected mechanically by its elasticity, it would be covetous of caloric, and would take it from any substance which touched it.

This theory will, I conceive, explain all the phenomena. A certain portion of water is converted into steam at the internal bottom of the kettle, which, in its quiescent state, under atmospheric pressure, would occupy the space, $w\ r$, but by its elasticity, or momentum of its particles, at the instant of its conversion it occupies the space, $w\ r'$, becomes colder than 212°, and thus takes heat from the bottom, reducing it below 212°, after the supply of heat from the fire has been removed. This reduction of heat can only happen whilst the water is boiling; after the water has ceased to boil, it soon communicates its own heat to the bottom, which explanation accords with the phenemona.

I cannot prove, by experiments, that when gas is liberated from its prison of a fluid or a solid, at the instant of its liberation it goes to occupy more space than it would do solely by the admitted laws of latent heat; but I suggest the following consideration, which may make this probable:—If a spring be fixed in a table, be bent towards the right, and afterwards released, it does not merely go back to the place where it will ultimately rest, but, by its elastic property, it would go considerably to the left, and would pass its resting-place several times before it be still. May not the spring held down by the finger on the right side, represent or bear an analogy to gas confined in a fluid or solid; and may not its proceeding to the left of its resting-place, represent its expanded condition immediately after it has gained its freedom?

I must now mention another circumstance, which is closely connected with, and comes in aid of, the present subject.

It has been observed, that on the first removal of any metallic vessel from the fire containing boiling water, the ebullition is increased. The solution may be this:—The cold air then surrounding and coming in contact with the outside of the vessel, by the subtraction of heat may cause its external surface to contract, and this may mechanically contract it internally, and so heat may be evolved. This explanation is nearly the converse of the previous one of the steam which has been given. There a chemical expansion first happens, followed by a mechanical expansion, by which heat is absorbed. Here, in the metal, a chemical contraction first happens, succeeded by a mechanical contraction, by which heat is evolved.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXI.

OF THE FACULTY OF SENSATION AND PERCEPTION, AND OF THE ORGANS BY WHICH MAN PERCEIVES THE PRESENCE OF THE EXTERNAL WORLD.

The whole organs of man may be divided into two great classes—namely, those by which he is nourished and grows and reproduces his kind; and secondly, those by which he perceives the presence of the external world, and the present and past order of things external to him, and by which he reacts upon them. This division of his organism or whole organization is not rigorous, and, therefore, not strictly philosophic; but it has been found to answer all practical, physiological, and even psychological purposes. It explains very beautifully how the first set of organs are chiefly occupied with merely building up the frame of the body, and have therefore been called *organic*, in contradistinction to the name given to the other or second set of organs, which, by reason of their seemingly belonging as it were exclusively to animals, have been called *animal*. Thus we have organs of organic life, and organs of animal life. The first includes the organs of

1. Prehension,	The lips.
2. Of Mastication,	The teeth.
3. Of Insalivation,	The organs forming the saliva.
4. Of Deglutition,	The cavity of the throat called the pharynx. This cavity may easily be seen by looking into the mouth; it leads directly into the gullet.
5. Of Digestion in its widest sense,	In the stomach, small and large intestines.
6. Of appendages of the digestive tube,	Liver, spleen, and pancreas.
7. Of absorption of the chyle,	The lacteal vessels.
8. Of circulation of the absorbed nourishing material — the chyle and blood,	The veins, the arteries, the heart.
9. Of nutrition, which includes in some measure the divisions 8, 7, and 6,	The ultimate distribution of these vessels, including the absorbents.
10. Of respiration,	The lungs; to these may be added the kidneys, whose office is further to purify the blood.

Now these organs construct the animal frame, but they

do not bestow upon it that complete character usually called *animal;* by which is meant, the exercise of the organs of the senses, and of spontaneous motion from place to place, performed by the muscles and their appendages, the bones and joints; of perception of bodies external to ourselves; of reflection or thought, of which a specific or peculiar kind has been bestowed by the Almighty on every distinct species of animal, precisely adapted to its position in the great scale or scheme of creation; in short, those organs and their functions by which the animal frame may avoid what is hurtful to it, and approach and seek what is calculated to give it pleasure. The organs of voice and speech are here included, and the *division* may be arranged as follows:—

1. Organs of sensation,............	The instruments of the senses: skin, tongue, nose, eyes, ears, and the nerves leading from these to the brain and spinal marrow.
2. Of perception and ratiocination with consciousness,..........	The brain.
3. Of perception and reflex action, but without consciousness,	The spinal marrow.
4. Of muscular action, with consciousness,.....................	The muscles and certain nerves.
5. Of muscular action, but without consciousness,............	Certain muscles, with the nerves supplying them.
6. Of voice,..........................	The larynx.

Thirdly, The reproductive organs are considered as entirely distinct from these two great divisions, and are considered apart, and merely in strictly professional works.

If the reader now consider the above plan even in any of its great outlines, he will immediately discover the happy adaptation of the functions and organs bestowed on each of the great divisions of living bodies, that is, animals and vegetables. Let him figure to himself the gigantic oak clothed or endowed with muscular power, and, in brief, with the power of motion such as animals possess! not fixed and rooted to the soil, but stepping out in straight lines, with or without reason, sweeping everything before it and rendering the earth immediately uninhabitable by man! A forest set in motion affrightening the inhabitants of the earth! On the other hand, nearly every animal, at least those possessing high endowments of such sensibility, possess invariably the power of withdrawing from what is hurtful; and poets have described with much, though fanciful truth, the fate of a human being shut up in the form of a tree, rooted to the soil, sensible and alive, but incapable of motion. Such a state, could it exist, would be the most pitiable and lamentable of all.

The organs of the senses, so valuable to all animals, but in an especial way to man himself, are usually reckoned five, from the days of Aristotle, the greatest Zoologist of all antiquity to the present day. Many very plausible arguments have been from time to time brought forward, endeavouring to show that the organs of the senses must be more numerous than five, if not in man, at least in some other animals; thus the surface of the human lips, the expanded integument of the arm of the bat, and the gelatinous, cylindrical shaped cavities found on the head of certain sharks, skate, and other cartilaginous fishes, have all been proposed as organs, exercising a new or a sixth sense, but the proofs of their being so, have never been fairly made out.

By virtue of the peculiar properties of their several nerves, the senses are said to make us acquainted with the states of our own body, and they also inform us of the qualities and changes of external nature, as far as they give rise to changes in the condition of the nerves; but in so far as regards the states of our own body, this is true only to a certain extent. Of all, or any of our internal organs we can have no notion through our unaided senses; and the phenomena of pain and of uneasy feelings, excited in us generally by a derangement or disorder of the internal organs,—such sensations of pain, as they are usually called, are probably transmitted to the brain, the seat of consciousness, by a peculiar set of nerves adapted for this peculiar use or purpose. Sensation, no doubt, is a property common to all the senses, but the *kind* of sensation is different in each; and thus we have the sensations of feeling or touch, of taste, of smell, of hearing, and of seeing. But it must be carefully kept in recollection that the human mind cannot perceive the external world in any way whatever; all that we do perceive is merely a property, or change of condition, of our nerves; now the imagination and reason are ever ready to make us believe that when we touch a body foreign to ourselves, the mind actually perceives the body so touched, whereas we merely perceive in the brain the change produced on the *extremity* of the nerve which has mediately come in contact with the material structure touched. It is the same with sight and with all the other senses, and hence arose the celebrated proposition of Berkeley, Bishop of Cloyne, "that as external agencies can give rise to no kind of sensations which cannot also be produced by internal causes exciting changes in the condition of our nerves, so no proof is derived through our senses of the actual existence of any material world." Before however proceeding further with the physiology of the senses, it is proper the reader have some idea of their mechanism or structure: and, first, of the *organ* of *touch or feeling.*

The sense of touch is not confined to particular parts of the body of small extent like our other senses, but, in its more limited sense, it is usually confined to the external integuments of the body, and in an especial manner to the extremities of the fingers and toes. In man these parts are peculiarly delicate and sensible, and the integument covering the fingers is obviously endowed with high capabilities; these it owes to the nerves which place it in connection with the spinal marrow, and through it with the brain.

STRUCTURE OF THE SKIN, AND OF ITS APPENDAGES.

The skin, or external integument, is accurately moulded upon the body; it conceals the inequalities and clothes the whole frame with great beauty, particularly in children and in women. It is extensile and also retractile to a certain extent; it is a sudorific or expellent and secreting surface, by which matters are removed from the blood which it were dangerous to retain in it, or even on the surface, for any length of time. Nature visits with much severity the habitual neglect of cleanliness, and of a due change of linen, by the production of numberless cases of cutaneous disorders, still so frequent in Ireland and Scotland; whilst the sudden stoppage of the perspiration gives rise to dangerous internal disorders. In a word, it is by no means improbable that the matter, thrown out at every moment, by, and from the skin, is of so highly poisonous a character, that its retention in the body may give rise to fevers, cholera, and to plague itself.

The skin has a free surface, and a fixed or adhering one; the free surface, or that exposed to the external atmosphere, is covered by a cuticle or scarf-skin, easily raised from it by blistering, and whose obvious use is to protect the more delicate nervous and vascular structures placed immediately beneath it. The particular nature of this scarf-skin or cuticle will be more particularly explained a little further on. Beneath the scarf-skin is a layer of tissue, deeply coloured in the negro and other dark races; it is called the *rete mucosum* of Malpighi, after its discoverer, a celebrated Italian observer. Its presence has been often questioned in the European skin, but to us it seems to be present, although but slightly coloured; in the Albino of all races, the colouring portion of this *mucous layer* is clearly wanting altogether, but still the mucous layer itself may be present even in the Albino. The presence of this coloured layer of the integuments in the negro, must serve important purposes in his economy, for we observed that an Albino girl, born of Caffre parents, that is of jet black parents, whom we saw at Van Aards on the Grootevisch Riviere, in Southern Africa, and on the borders of Kafferland, suffered nearly as much from the heat as any European; that is, the exposed parts

of the skin were blistered by the action of the sun's rays as in ourselves.

Beneath the *rete mucosum* is the true skin, the *dermis* or *corion.* This is of very considerable strength and even thickness, especially on the back; it is of a close, dense interwoven tissue, and abounds with nerves and blood vessels; its connection with the filamentous or cellular tissue beneath it, is of course intimate, and necessary for its vitality; it is here, of course, that the fixed surface of the skin exists.

It might be supposed sufficient for the purposes of this work, to have described the skin or the integuments of the body as above; but it is from a want of more minute elementary knowledge, that many popular notions are not only incorrect but absolutely hurtful. The very term *surface* leads many to suppose that the mere integuments cannot be of much consequence, at least anatomically and physiologically considered. Now this is a great error, for the robe or external covering of all animals has characters of the greatest constancy, and as accurately define the animal as any other structure whatever.

On the free surface then of the integuments we observe folds, wrinkles, and furrows; those in the palm of the hand were made the subject of a silly art called Palmistry, derived from oriental nations—from races of men whose minds were either not properly educated, or who from nature have received a bias towards a belief in mysteries and follies of all descriptions—who have no natural love for *scientific truths*, and who cannot be made to comprehend the true physical relations of cause and effect.

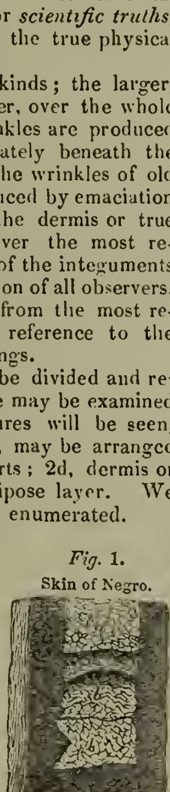
These folds or wrinkles are of several kinds; the larger, are observed around the joints, the smaller, over the whole surface of the skin. The folds called wrinkles are produced by the action of muscles placed immediately beneath the skin, as on the forehead and temples. The wrinkles of old age, in various parts of the body, are produced by emaciation and the loss of the retractile power of the dermis or true skin. A difference in colour is, however the most remarkable circumstance in the appearance of the integuments of men, and has strongly arrested the attention of all observers. The negro race has existed, as it now is, from the most remote antiquity, as may be proved by a reference to the paintings on the tombs of the Egyptian kings.

If a portion of the human integuments be divided and removed from the body, so that the cut edge may be examined with a magnifying glass, certain structures will be seen, which, for the convenience of description, may be arranged under three heads; namely, epidermic parts; 2d, dermis or corion; 3d, subcutaneous cellular and adipose layer. We shall speak of these layers in the order just enumerated.

Anatomists have been forced to have recourse to the skin of the whale, the elephant, and of many other animals, in order to determine by analogy the nature of parts, which, from their tenuity and delicacy, could not be well made out in the human skin. 1. The epidermis or cuticle, marked *b*, is the outermost of all the epidermic parts of the integuments; it is to it that the term scarf-skin is always given; it is semi-transparent, and in some measure a horny layer moulded upon the surface of the true skin, over all the papillæ or nervous and vascular prominences, like a coat of varnish, effectually protecting the tender and delicate surface from the action of external agents. The epidermis is represented at *b* fig. 1, and *a b* fig. 2; but the reader, rightly to understand its structure, and that of all those to follow, must handle and examine them for himself; otherwise, extremely erroneous notions are sure to be the result of studying or learning any material object from books and figures alone, neglecting the invaluable and indeed essential knowledge we derive through the use of the fingers. The very instrument, indeed, which we now examine, the instrument of touch, is that by which and through which, we derive by far the greatest part of all sound knowledge of the material world.

Fig. 1.

Skin of Negro.



a, The cutis, dermis, or true skin; *b′*, the pigmentum, or colouring matter of the lymphatic network; *b*, the epidermis or cuticle.

When the epidermis or scarf-skin is stripped off, its inner or deeper surface is observed to be covered with little pits or depressions; in the skin of the negro, the colouring matter occupies these little pits, but still is said to be found in greater abundance between the nervous papillæ than upon them. But the scarf-skin seems here also to be somewhat coloured in the negro.

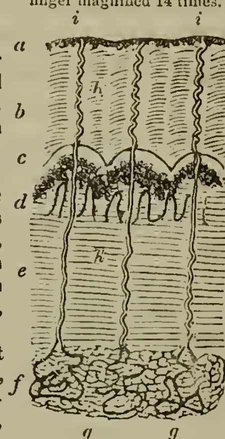
When the scarf-skin is being removed from the parts below, a great number of fine transparent filaments may be observed, which are torn through in separating the one from the other; these filaments are supposed to be vessels which pour out the perspiration, whilst others have supposed them to be merely the lining membrane of other tubes, more lately described.

A great objection to this view of the filaments alluded to above, is that they may be seen with the naked eye, whereas the spiral tubes of the sudoriferous glands, whose lining membrane they have been supposed to be, can only be seen with a good glass; fifty of these orifices open within the space of a square line.

Beneath the epidermis, properly so called, may be seen, in the above figure, the other epidermic parts which are still called rete mucosum, pigmentum, &c. These parts which much resemble the scarf-skin, form sheaths over the nervous papillæ, as may be seen in fig. 2.

Fig. 2.

Section of the skin of the finger magnified 14 times.



a b, The epidermis; *c*, colouring matter or pigmentum; *d*, rete mucosum of Malpighi; *e*, the dermis or true skin: *f*, subcutaneous and adipose tissue; *g g*, sudoriferous glands; *h h*, spiral canals going from these glands, and terminating on the surface at *i i*.

The epidermic parts are of vast thickness in the skin of the whale, and it is on it that the greater number of discoveries have been made, with reference to the integuments generally. All these layers are insensible, and by some are called inorganic; they are probably merely not essentially vascular. Thin, flattened, horny corpuscles are deposited on the surface of the true skin; these hardened on the surface form the epidermis properly so called, while the corpuscles beneath form the pigment and rete mucosum. Fine scales are continually being thrown off by the epidermis and replaced by the subjacent ones.

The pigment seems to exist in all varieties of the human race, varying however greatly in the depth of colour; it appears *partially* even in the white races, and has been observed in them to be fully as dark as in the negro, but confined merely to a small portion of the skin; hence has arisen the opinion, first maintained by Azara, that such accidental varieties might extend, become hereditary, and thus explain the colouration of the negro and other dark races; this opinion is merely hypothetical.

The dermis, or the true skin, is situated beneath all those parts, and is properly the basis of the integument. It varies very much in thickness, being thickened usually on the back, and over the cranium; also on the palms and soles of the feet. On the deep surface—that namely by which it adheres to the living structures beneath it—a number of conical depressions may be observed; into these project masses of fat. When the skin is separated extensively from the parts beneath it, it is apt to slough or die, for a very obvious reason, being then cut off from the sources supplying it with blood. When examined microscopically, it is found to be cellular and fibrous, and is resolved into gelatine by boiling, and by tanning is converted into leather. The elasticity of the dermis seems to depend more on the arrangement of its texture, than on the intimate nature of that texture. The papillæ are those

eminences seen on the surface, and which in the hands and feet are arranged in rows; they are nervous and vascular, and seem analogous to those much larger, visible on the tongue. On the outer surface of the dermis lies a network of exceedingly fine lymphatic vessels, discovered by the celebrated Mascagin. The presence of these vessels explains the absorption into the blood of fluids or solids, rubbed through the epidermic parts.

Beneath this important part of the human integuments, is the layer called the subcutaneous cellular and adipose tissue; in young persons, and especially in women, the fat forms a complete layer under the skin, sometimes of very considerable thickness, giving to their forms that agreeable appearance, indicative of youth and health; its usual absence, or at least partial deficiency, allows in man the form of the skeleton, muscles, and tendons, to be more especially observed. In some animals, called pachydermatous or thick-skinned, it also forms a remarkable subcutaneous layer, as in the pig, hippopotamus, and probably the tapir. In whales, the layer of fat forming the blubber is not confined to the subcutaneous cellular tissue, but extends deeply into the tissue of the skin itself. Various uses have been assigned for its abundance in whales, but none of them are at all satisfactory.

APPENDAGES OF THE SKIN.

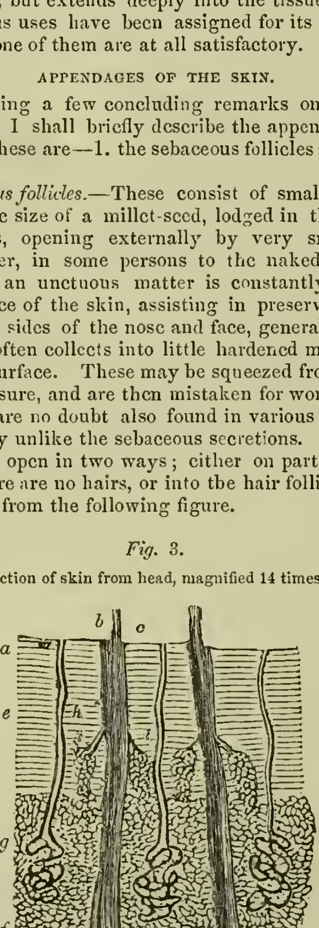
Before making a few concluding remarks on the physiology of touch, I shall briefly describe the appendages of the human skin: these are—1. the sebaceous follicles; 2. the nails; 3. the hair.

The *sebaceous follicles.*—These consist of small pouches or bags, about the size of a millet-seed, lodged in the substance of the dermis, opening externally by very small orifices, visible, however, in some persons to the naked eye. From these orifices an unctuous matter is constantly poured out upon the surface of the skin, assisting in preserving its flexibility; on the sides of the nose and face, generally, the sebaceous matter often collects into little hardened masses, discoloured on the surface. These may be squeezed from the bag or cavity by pressure, and are then mistaken for worms. Microscopic worms are no doubt also found in various follicles, but they are totally unlike the sebaceous secretions.

The follicles open in two ways; either on parts of the surface where there are no hairs, or into the hair follicles, as may be understood from the following figure.

Fig. 3.

Section of skin from head, magnified 14 times.



i i, Sebaceous follicles; *c*, Hair follicles; *g*, Sudoriferous glands; *f*, Subcutaneous cellular and adipose tissue; *e*, The dermis; *a*, The epidermic parts; *b*, The projecting parts of the hair.

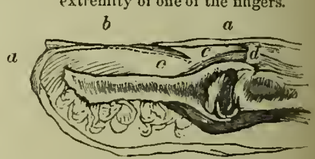
It is generally admitted that the more common description of wen, frequently found on the scalp, is formed merely by an accumulation of the albuminous and fatty matters collected in one or more of these follicles.

Of the nails and hair.—In man these are but little developed, compared with almost any other animal of the same great class. In most hot-blooded quadrupeds, the system of the nails and hair covers nearly the whole surface of the body; and even in the elephant and hippopotamus, where the hairs are scanty, their place is amply supplied by the thickness of the epidermic parts. So also in whales. We shall first speak of the nails.

The human nails, more especially those of the fingers, are hard, flexible, elastic, and translucent. When well-formed they have a specific elongated character, but in many persons they are ill-formed, and approach more or less to the form of the claw, that is, become pointed. For the sake of description, the nail is divided by anatomists into *root*, *body*, and *free portion.* The root is covered on both surfaces, and is only seen on dissection; the body is covered only on one surface; the free portion is free on both sides. This free portion has a tendency, when left to grow to its full extent, to become incurvated, and in consumptive persons remarkably so, caused probably by the atropby of the subjacent soft parts. The root is about a fourth the length of the body of the nail, and is its thinnest part; it is received into a fold or duplicature of the skin, *c c*, to which it is attached by both surfaces; but these attachments are but slight, compared with that by which the body of the nail is fixed to the sensitive parts beneath it. It is this connection chiefly which renders the tearing of the nails forcibly from their roots so very painful an operation; an operation, however, which is sometimes required.

Fig. 4.

Representing a vertical section of the extremity of one of the fingers.



d, The dermis; *c c*, Duplicature of skin; *b*, Body of the nail; *a*, Epidermis.

The nail is separated from the bone by a very thick portion of the dermis or true skin, exquisitely sensible, and very vascular; a fine part of the nail, at the part nearest to the skin, is called the *lunula*; it is somewhat crescent-shaped, and is supposed to show a slight discoloration even in those mestizzoes, whose blood might otherwise be supposed to be pure. Authors are not agreed as to the ultimate connection of the epidermis with the nail. They are, however, in their nature strictly analogous, also in their chemical composition.

Nails then are not vascular parts, but are the products of secretion, and are also, as it were, excretions; a diseased nail is produced merely by a disease in the part producing it. They have been compared to the teeth, and are no doubt a substance of precisely the same horny nature, as the nail takes the place of the teeth in the whale; but still the analogy is remote. The young whale before birth has teeth in both jaws, although they never become properly developed; that is, in whalebone whales. Whalebone then is merely a substitute for, but not identical with the teeth in any sense whatever; and they have not at all the same chemical composition. The nails grow continually in length, as may be proved by a very simple experiment. In civilized life they require attention and even care; in savage life, all such matters are adjusted by nature.

ILLUSTRATIONS OF MECHANICAL DRAWING.

CHAPTER VI.

In the last article, a general explanation was given of the nature of geometrical projections of machinery, of the principles upon which they are, to a certain extent, derivable one from another, and of their peculiar adaptations to the purposes of mechanical representation.

Our business will now be, to render familiar to the student the methods of delineating mechanical objects in particular, to present detailed accounts of the processes of geometrical projection, and so to facilitate his progress in the art, as to enable him to lay correctly down upon paper any combination of mechanical ideas which he may wish to preserve.

The first thing to be attended to, in contemplating the execution

The human teeth in an adult amount in number to thirty-two, sixteen being placed in each jaw. These are divided into four incisors or cutting teeth, or front teeth—two canine or dog teeth—four tricuspid or smaller grinders or molars, and six grinding teeth, or larger grinders or molars. Each of these is divisible into the root, neck, and crown. The teeth of different animals vary considerably. The tusks of the elephant, being hard and compact, are called ivory. Carious teeth are tetracased teeth, on which a species of earthy matter takes place, and appears to be quite distinct from ulceration. The chemical analysis clearly points this out. A carious tooth, with a specific gravity 1·533, yielded

Cartilage,	57·78
Phosphate of lime,	30·00
Carbonate of lime,	2·09
Magnesia,	2·05
Chloride of potassium,	1·25
Moisture,	9·45

BONES.

The following table exhibits a comparative view of the chemical composition of various bony structures :—

	Bone.	Human Ivory.	Enamel.	Bony Tumour.
Cartilage,	35·93	25·38	7·84	21·12
Phosphate of lime,	51·12	54·14	76·73	65·80
Carbonate of lime,	9·77	5·76	7·67	4·84
Phosphate of magnesia,	0·63	1·37	4·09	trace.
Chlorides of potassium and sodium,	0·59	3·02	2·87	
Water,		10·37		8·72
Silica,		0·33	0·63	

The tartar of the teeth is a familiar substance. It is said to form most readily in the mouths of persons who speak much, or who hold their mouths open. It seems to be deposited from the saliva, as it contains similar ingredients. The best method of removing tartar from the teeth, or preventing its formation, is by washing the teeth every day with a brush, upon which may be placed a small quantity of very finely powdered chalk.

III.—Deglutition, or Swallowing.

The operation of mastication is a voluntary act; but the next step, or that of deglutition or swallowing, is of a different character. So soon as the food is sufficiently reduced to a pulpy state, the natural impulse seems to be to carry it by the assistance of the tongue to the back part of the mouth. This is all the voluntary exertion that is required on the part of the individual. The instant that it touches certain nerves which guard the throat, with this object in view, they are excited, and carry the impression to the spinal marrow. This impression is conveyed or reflected by a different nerve to the point of excitement, and motion is the result; this motion being the contraction of the gullet, and consequent grasping of the morsel, which is quickly conveyed by this important canal into the digestive organ, the stomach.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXII.

ON THE FACULTY OF SENSATION AND PERCEPTION—APPENDAGES OF THE SKIN—*Continued.*

Structure and Growth of the Hairs.—The extremity of the hair, which is inserted into the skin, is contained in a sort of follicle. This *hair follicle* (in the annexed figure, *e*) is the organ which forms the hair; it is imbedded in the cellular tissue under the skin, and is prolonged to the surface of the skin by a sort of membranous canal. The *hair follicle* consists essentially of a pouch or *sac*, and a *papilla.* The membranous *pouch* or *sac*, *c*, *c*, has a narrow neck, and opens externally by a contracted opening, through which the hair, *b*, passes, without at all adhering to it. The walls of the sac are translucent. The inner surface of the sac, *c*, is smooth, not adherent to the hair, but separated from it by a reddish liquid.

Structure and Growth of Hair magnified.

e, Hair follicle.
g, Subcutaneous cellular tissue.
c, *c*, Membranous pouch or sac.
b, The hair.
a, Papilla.
f, The dermis.

From the bottom of the sac—that is, its deepest part—a *papilla* (*a*) nervous and vascular, arises: the papilla is of course fixed at the base, for here the nerves and blood-vessels enter it; but on the apex, or upper part, it is free, and this free part extends nearly to the narrow orifice above spoken of; and, as is said, in the disease called plica polonica, it extends even beyond it. Now, upon this papilla the hair is formed: first, a conical horny sheath is moulded upon the surface of the papilla, as the teeth are formed over the dental sac or follicle; on the inner side of this another and another cone succeeds, thus ultimately protruding as the hair. Into each hair follicle, one or more sebaceous follicles pour their secretions; and it is generally supposed that a very thin layer of scarf-skin lines the interior of the hair follicle.

The disorders to which the skin is liable are extremely numerous; many of them dangerous and obstinate, and some alarmingly disgusting. Leprosy, for example, and elephantiasis, the former the lepra of the Greeks and Hebrews, the latter the lepra of the Arabs, are frightful and loathsome diseases, which at one time were found over all Europe. Even yet, the lepra of the Greeks and Hebrews, or common leprosy, is by no means unfrequent, and even the elephantiasis, a frightful tubercular disease, existed very lately so far north as Shetland. The Hebrew and the Gipsy race are still subject to the common leprosy; and it is not an im probable theory, that certain skin diseases are peculiar to certain races, just as it is said that certain intestinal worms are peculiar to certain races of men. In this way, these diseases may have found their way into the northern parts of Europe about the time of the crusades, not by their being contagious, but by the progeny of intermingled races. But further observations on skin diseases would be quite misplaced in a work of this kind, the proper object of which is to submit to the reader a concise but accurate idea of the structure and functions of the organs composing his own frame chiefly.

We shall therefore conclude the history of this organ of sense, the organ of touch, with a few remarks on a disorder, not dangerous it is true, but exceedingly irksome and vexations—we mean *corns.*

Corns are hard, horny, generally conical-shaped bodies, developed in the epidermic parts, and more especially as it would appear in the rete mucosum; they seem to grow with the apex or point of the cone inwards, the base being turned towards the scarf skin; hence, when the pressure of the shoe acts upon them, the point is forced inwards through the quick and tender true skin, which it at last pierces, thus reacting upon the subcutaneous cellular tissue. It is this no doubt which causes such excruciating pain when pressure is made over a corn. They, probably, are natural to many persons, and do not seem to have been in such individuals caused by tight shoes, or other mechanical means. During some variable seasons they are peculiarly troublesome. Their removal probably might be effected by repeated blistering and warm fomentations. The disease called bunions by many surgeons, is a dislocation of the first joint of the great toe from off the large head of the metatarsal bone supporting it. The

rounded head of this bone they mistake for a tumour; the real nature of the complaint will be fully explained in a concluding article on the form and structure of the foot in man and woman.

All the functions of the skin, and the importance of a due performance of these to the animal economy, are not as yet well understood. The care bestowed by the groom in cleansing, washing, and brushing the surface of the horse, after the severe toil of the chase or race, sufficiently proves its importance as regards the horse at least; whilst in man, if the linens or body clothes be not frequently changed, the use of the bath seems absolutely essential for the maintenance of a healthy condition. In very cold countries, as in Russia, where the perspiration is so much checked, the vapour-bath has been considered as the sole means of preserving the population from a wide-spreading and desolating scurvy; and even in otherwise temperate climates, without due exercise, and some attention at least to cleanliness, scurvy and other cutaneous disorders are apt to appear, especially if salted food be at the same time used freely. But in warm and tropical climates, where the perspiration flows freely and without effort, strong exercise is not only not necessary for the European, but may be positively hurtful to him: no European can stand strong exercise in a hot climate.

On theoretical, but by no means improbable grounds, it has been conjectured that peculiar states of the atmosphere may so check certain of the secretions of the skin as to throw them into the mass of blood, thus giving rise to symptoms resembling those produced by poisons.

An extensive loss of skin by operations, ulcers, or scalds and burns, is always productive of much inconvenience to the sufferer. On the shins or legs, for example, a trifling loss of skin by ulcer or otherwise, disqualifies the person from being received as a recruit to serve in the army; and when the loss happens to be on the face, many ingenious attempts have been made to replace it, by substituting for the lost portion another cut from a less exposed part. In this way, lips have been restored—partially at least; and a lost nose replaced by a portion of the integuments of the forehead. It is extremely probable that many such operations would succeed in very young persons, which unfortunately fail in those more advanced in years. When portions of the skin have been stripped off by violence, but still adhere partially, the surgeon ought to make every attempt, in general by replacing the integuments so removed, by a few judicious stitches and *very careful handling*, to enable the skin so injured to recover its vital connexions with the surrounding parts. There is a plastic healing force in the young, which is not found in aged persons. Surgeons to manufactories, mines, &c., cannot be too cautious in such matters.

THE SENSE OF TOUCH.

Some remarks—which, however, must be brief—on the physiology of this sense, the sense of touch, may appropriately enough close this section.

It is usual to consider the sense of touch as not confined to any particular part of the body, but extended over all. Even the internal organs are presumed to have a kind of sense of touch. This, I think, in their ordinary condition is very questionable. The sensitive nerves all over the body, whether belonging to the external integuments or not, are presumed to come from the posterior roots of the spinal nerves. But the fingers and toes in man, the extremity of the proboscis in the elephant, the tongue and lips in many animals, the nose in the pig and tepir; these are the parts fully invested with the requisite sensibility. Most headaches arise merely from the state of the external integuments of the head; still there are others, as has been proved by dissection, which have a deeper seat, thus showing that some parts of the brain are sensible whilst others are not.

Sensations, as those of touch, may arise from two sources: they may arise either from irritation applied to the nerves, or from stimuli applied to their peripheral extremities; that is to the surfaces in which they terminate, whether these be the integuments or otherwise. Thus, the horny tissue and the teeth are quite insensible, and in the healthy state so are the bones, tendons, and cartilages. When diseased, the bones become acutely sensible.

It is a curious fact, that the skin itself is not equally sensible throughout; two small bodies applied to the surface are not equally well recognised at every part as distinct from each other; the same happens in respect to temperature, and even to pressure.

The sensibility of the inner surfaces or lining membrane of the windpipe and organ of voice, is very great; that of the mouth and of the gullet less so. The lining membrane of the intestines is not particularly sensible; all which differences may and probably do depend on peculiarities in the nerves distributed to the structures respectively.

The sensation of a blow or shock may arise as well from internal as from external causes, or, in the language of metaphysics, may as well originate in a substantive affection as be occasioned by an objective reality. Thus, *feeling* is not the absolutely naked truth it is vulgarly supposed, since a body may be imagined to be felt, may be actually felt, by the person, and yet have no real existence. The sense of touch then has its delusions like the others.

The same remarks apply to the sensations of heat and cold, which are generally caused by external agencies; the burning heat and shivering cold of ague is of course entirely independent of any such agencies, arising solely from internal changes, and not remediable by any application of their opposites. A person in the cold stage of ague will continue to shiver though immersed over head in a hot bath; heat is not felt on the surface at that moment. What is called the muscular sense is a phenomenon not easily reducible to common sensation; it was first observed by Detnot De Tracy. Thus, when we raise a vessel, with the contents of which we are not acquainted, the force we employ is determined by the idea we have conceived of its weight. In descending a stair also, the probable depth of the steps is accurately guessed at or conjectured. Should a step be found much deeper than what was calculated on, the body descends very rapidly, or rather falls, and the person may receive a severe shock. When a person ignorant of the weight of quicksilver first takes up a bottle containing a considerable quantity of it, he is extremely apt to let it fall, from a miscalculation of the muscular force requisite, precisely as in descending a stair and encountering a deeper step than was expected. But if the attention be previously roused to the danger, then the muscular forces are calculated to a nicety, and with incredible rapidity; for this, however, the use of sight is absolutely requisite.

The sense of touch is subject to an illusion of an extraordinary kind, which cannot be corrected even by the sight; thus proving that the senses alone, unaided by the reasoning powers, are not to be trusted—cannot indeed be believed on all occasions. The illusion or delusion to which we allude attracted even the attention of Aristotle, so early was it observed, nor to this day has it been fully explained. It is this:—"If we place on a table, or on the palm of the hand, a marble or any other small globular body, and crossing it alternately with the fore and middle fingers,

crossed so that the marble shall only touch the outer edges or surfaces of the two fingers, the person will believe

that he touches two marbles, although he knows that only one is present." There is an expression in the above quotation to which I would particularly advert, because some continental physiologists would seem to consider the circumstance as essential in the production of the phenomenon, whereas it is not; I mean the touching the marble with the *edges* of the *fingers*. Now, any portion of the lower surface of the finger answers quite as well, and it is this which seems to have escaped the notice of the continental physiologists generally, which renders the explanation they offer of this curious illusion unsatisfactory. The explanation generally admitted is as follows:—The mind refers involuntarily all sensations experienced at different points of the body, to the position in which such points are usually placed. Now, the crossing the fingers does not prevent us feeling either of them in contact with the marble, as if they were placed naturally side by side. But in the habitual position of the fingers side by side, it is impossible that the outer edges of any two fingers be at the same time placed in sufficient contact with a single marble or other similar rounded body; and thus, when such contact actually takes place simultaneously, in respect to the two fingers, effected by the contrivance of crossing the fingers, then the mind, involuntarily believing the thing impossible, takes it for granted that two marbles, not one, must be present, and hence arises the sensation and perception of two distinct bodies. This is the explanation of the singular illusion we speak of, first offered by Condorcet, and maintained afterwards by Müller and by many others, and we believe it is very generally admitted. But there lies against this explanation the seemingly unanswerable objection, that it is not necessary to touch the marble with the *opposite edges* or margins of the two fingers; the rounded surface over the pulp suffices. There is something, then, in the crossing of the fingers which we do not understand. Another curious circumstance may be mentioned in connection with the illusion. If the middle finger be crossed over the fore-finger, which is the usual mode of performing the experiment, the surface touched with the end of the middle finger will seem to us to be most remote, although in point of fact the finger is at that moment nearest to us.

Other curious phenomena have been adduced by physiologists in support of Condorcet's opinion. If by any cause whatever the lips come to be accidentally deformed, and if we then apply to them a body, a glass, for example, or cup, with whose form we are habituated, the mind will involuntarily refer the deformity to the cup or glass itself, whose curve will seem broken, thickened, or irregular. It has even been asserted that those persons who have had a new nose supplied from the skin of the forehead, to replace one lost by disease or accident, will refer any irritation produced in the new nose, not to that particular part of the body, but to the forehead from whence the new nose was taken. Such remarks require confirmation. To the same cause has been referred the pains felt in the toes by those who had long previously lost their limbs by amputation.

MATHEMATICS.

PRINCIPLES OF ALGEBRA.

Chapter VI.—Interpretation of Anomalous Solutions.

Every equation of the first degree—that is, every simple equation—may be so reduced as to have all its signs positive,* and be of the general form.

$$a x + b = c x + d.$$

* We can always change the negative terms of the equation into others which are positive, since we can always add any quantity to both members.

By subtracting $c x + b$ from each member of this equation, we get

$$a x - c x = d - b; \quad \text{whence} \quad x = \frac{d-b}{a-c}.$$

60. *Anomaly* 1.—Let it now happen that d is less than b, but a greater than c, there is then an impossible subtraction, $d - b$, in the numerator of this result. This shows that the solution is irrational; and if we examine the equation from which it is produced, we find that, on the supposition made, it is absurd: for if a be greater than c, then is $a x$ greater than $c x$; and if b also be greater than d, then is $a x + b$ greater than $c x + d$, and cannot be equal to it.

This gives rise to these questions:—1. Can such an equation arise from a problem? 2. If so, is it the problem itself which is absurd, or the way of treating it? 3. If the latter, how is the method of solution to be rectified?

Problem I. *In illustration.*—In the year 1853, A's age is 40, and B's 12. Required the date at which A's age is three times that of B.

This date must either be *before* or *after* 1853; that is, either $1853 - x$, or $1853 + x$. Try the first case. Then, in $1853 - x$, A's age *was* $40 - x$, and B's *was* $12 - x$, and the condition is

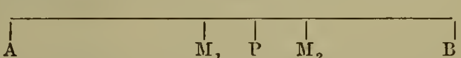
$$40 - x = 3\,(12 - x) \quad \text{whence} \quad x = \frac{36-40}{2}$$

which is impossible; and it is sufficiently evident that the equation is not true; for $40 - x$ must be greater than $3\,(12 - x)$ or $36 - 3x$. Now, try the second case, $1853 + x$. Then A's age *will be* $40 + x$, and B's *will be* $12 + x$, and the condition is

$$40 + x = 3\,(12 + x) \quad \text{whence} \quad x = \frac{40-36}{2}$$

which is possible, and gives $x = 2$, an evidently true answer; for in the year $1853 + 2$, or 1855, A's age will be 42, and B's will be 14, and $42 = 3 \times 14$. In this instance, then, the impossible subtraction arose from our assuming a date *before* instead of *after* a given epoch.

Problem II. *In illustration.*—A and B are 100 miles distant from each other, and 55 and 45 respectively from P. They start at the same instant to meet each other, and travel 10 miles and 7 miles an hour respectively. At what distance from P do they meet?



1°. Suppose that they meet at M_1; that is, let $PM_1 = x$.

Then A moves through $AM_1 = 55 - x$ in $\frac{55-x}{10}$ hours.

And B moves through $BM_1 = 45 + x$ in $\frac{45+x}{7}$ hours.

But A and B travel the same number of hours, therefore the equation for x is

$$\frac{55-x}{10} = \frac{45+x}{7} \quad \text{whence} \quad x = \frac{385-450}{17}$$

which is impossible, and it is otherwise evident that the equation is not true; for $\frac{55-x}{10}$ is $= 5\frac{1}{2} - \frac{x}{10}$ and $\frac{45+x}{7}$ is $= 6\frac{3}{7} + \frac{x}{7}$ and $5\frac{1}{2} - \frac{x}{10}$ must be less than $6\frac{3}{7} + \frac{x}{7}$ and not equal to it.

2°. Suppose that they meet at M_2; that is, let $PM_2 = x$.

Then A moves through $AM_2 = 55 + x$ in $\frac{55+x}{10}$ hours.

And B moves through $BM_2 = 45 - x$ in $\frac{45-x}{7}$ hours.

And these times being equal by the question, consequently

$$\frac{55+x}{10} = \frac{45-x}{7} \quad \text{whence} \quad x = \frac{450-385}{17}$$

which is possible, and gives $x = 3\frac{13}{17}$ miles. From this we conclude that the point of meeting is M_2 and not M_1; and the correctness of the solution is easily proved by verification. In this instance, then, the impossible subtraction occurred in consequence of x being taken in a direction exactly opposite to the true one.

61. Comparing the equations formed from these problems, we find

From Problem I.

Incorrect, $40 - x = 3\,(12 - x)$, or $x = \dfrac{36 - 40}{2}$ years *before* 1853.

Correct, $40 + x = 3\,(12 + x)$, or $x = \dfrac{40 - 36}{2}$ years *after* 1853.

From Problem II.

Incorrect, $\dfrac{55 - x}{10} = \dfrac{45 + x}{7}$, or $x = \dfrac{385 - 450}{17}$ miles *west* of P.

Correct, $\dfrac{55 + x}{10} = \dfrac{45 - x}{7}$, or $x = \dfrac{450 - 385}{17}$ miles *east* of P.

From these instances, the following principle will be understood:—

1°. When the value of x deduced from an equation, contains an impossible subtraction, the meaning of x has been misunderstood in forming that equation, and requires to be altered.

2°. The equation will be corrected by changing the sign of every term which contains x *only once as a factor*. [The rule is not extended to such terms as xx, xxx.]

3°. The result will be corrected by inverting the terms of the impossible subtraction, (that is, by changing $36 - 40$ into $40 - 36$) and giving to x a meaning directly opposite to that which was supposed when the incorrect equation was obtained.

Example.—The state of A and B's affairs is such, that if they gain £200 and £100 respectively, A will be half as rich as B; but if they gain £700 and £200 respectively, A will be twice as rich as B. What is the actual state of their affairs?

Three cases present themselves:—1. Both parties may possess property. 2. Both may be in debt. 3. One may have property, and the other only debt.

Try the first of these suppositions, and let A's *property* be £x.

Then £$(x + 200)$ = A's property when he has gained £200.

When B has gained £100, he is twice as rich as A is after gaining £200.

$\therefore$ £$2\,(x + 200)$ = B's property when he has gained £100.

And £$2\,(x + 200)$ — £100 = £$(2x + 300)$ = B's original property.

Again: £$(x + 700)$ = A's property when he has gained £700.

£$(2\,x + 300)$ + £200 = B's property when he has gained £200.

By the question, A is now twice as rich as B; consequently,

$$\frac{x + 700}{2} = (2\,x + 300) + 200, \quad \text{whence} \quad x = \frac{700 - 1000}{3}$$

which is impossible. Try the second case, and modify the equation by 2°, and let £x be A's *debt*. This gives

$$\frac{700 - x}{2} = (300 - 2x) + 200, \quad \text{whence} \quad x = \frac{1000 - 700}{3}$$

and $\therefore x =$ £100. This explains A's circumstances. To find out B's, we know that when A has gained £200, his property is £$(200 - x)$; and therefore, by the question, the property of B is £$2(200 - x)$ when he has gained £100; consequently,

£100 — £$2(200 - x)$ = £$(2x - 300)$ is B's *debt* = £200 — £300

£100 + £$2(200 - x)$ = £$(300 - 2x)$ is B's *property* = £300 — £200 or £100. The answer to the question therefore is: A is in debt £100, and B has £100.

62. *Anomaly* 2.—The solution of $a\,x + b = c\,x + d$ is $x = \dfrac{d - b}{a - c}$. If it should now happen that d is greater than b, and c greater than a, there is then an impossible subtraction in the denominator of the result, and it is otherwise obvious that the equation is absurd; for c and d being greater than a and b, there is $c\,x + d$ greater than $a\,x + b$, and not equal to it. Let the sign of those terms containing x be changed; the proposed equation then becomes

$$b - a\,x = d - c\,x \quad \text{which gives} \quad x = \frac{d - b}{c - a}$$

and this is possible. This anomaly then resolves itself into the preceding, and the equation and result are rectified in the same way.

Problem *in illustration.*—A and B, in the course of a journey between the towns of C and D, travel in the same direction; A at the rate of 9 miles an hour, and B at the rate of 7. They are, at the same moment of time, at A and B, distant 20 miles from each other. At what point between C and D are they together?

The problem does not state whether they travel towards C or D. Suppose then that they travel towards C, and are together at M_1, and let $AM_1 = x$.

Then A moves through $AM_1 = x\,\dfrac{x}{9}$ hours.

And B moves through $BM_1 = 20 + x$ in $\dfrac{20 + x}{7}$ hours.

These times are equal $\therefore \dfrac{x}{9} = \dfrac{20 - x}{7}$ whence $x = \dfrac{180}{7 - 9}$

which is impossible. Suppose now that they travel towards D, and let $AM_2 = x$.

Then A moves through $AM_2 = x$ in $\dfrac{x}{9}$ hours.

And B moves through $BM_2 = x - 20$ in $\dfrac{x - 20}{7}$ hours.

The times are equal $\therefore \dfrac{x}{9} = \dfrac{x - 20}{7}$ whence $x = \dfrac{180}{9 - 7}$

which is possible, and gives $x = 90$ miles. The answer then is: If they travel towards C, they *were* together at M_2; and if they travel towards D, they *will be* together at M_2; and M_2 is 90 miles from A's present situation, and 90 — 20 or 70 from B's.

[It is at once obvious that $\dfrac{180}{9 - 7}$ is a correction of $\dfrac{180}{7 - 9}$, but it is not so obvious that $\dfrac{x}{9} = \dfrac{x - 20}{7}$ is a correction of $\dfrac{x}{9} = \dfrac{20 + x}{7}$. By transposition, this last becomes $\dfrac{20 + x}{7} - \dfrac{x}{9} = 0$; and changing the sign of x, we get $\dfrac{x}{9} + \dfrac{20 + x}{7} = 0$, or $\dfrac{x}{9} - \dfrac{x - 20}{7} = 0$, whence $\dfrac{x}{9} = \dfrac{x - 20}{7}$.]

Exercise.—A's age is 30, and B's 9. When *will* A be four times as old as B? *Ans.* Never; but A *was* four times as old as B two years *ago*.

63. *Anomaly* 3.—If in solving $a\,x + d = c\,x + d$, thus: $a\,x - c\,x = d - b$, or $x = \dfrac{d - b}{a - c}$, we afterwards find that a is less than c, and d less than b, it shows that in subtracting $c\,x + b$ from each side of the equation, we have subtracted too much, since by this supposition both sides are less than $c\,x + b$. Subtract then $a\,x + d$, and we get

$$b - d = c\,x - a\,x, \quad \text{whence} \quad x = \frac{b - d}{c - d}$$

and the subtractions are both possible. This then resolves itself into the *error of process* noticed in Art. 71, and does not arise from a misconception of the problem.

digested in the stomach and bowels is introduced into the system, and mingled with the blood in a crude or half-assimilated state, and that it requires to undergo a second digestion within the blood-vessels before it is perfectly assimilated. It is a highly interesting inquiry, by what means this second digestion in the blood-vessels is effected. The analogy of plants would indicate the lungs as being the principal agents; for we find the crude sap brought by the sap-vessels to the leaves or organs of respiration, converted by them into the *succus proprius*, or true blood of the plant.

The respiratory act in man is not confined to the lungs, but takes place in every part of the system to which the absorbed oxygen is carried by the arterial blood; but it is a confirmation of the view just suggested, that at no time do we feel the want of free air more severely than soon after a full meal. In all probability, however, the process of assimilation in the animal body is more complicated than in plants, and may require the co-operation of various organs.

It is at present a matter of doubt among physiologists whether the primary nutritious liquid prepared by the digestive organs is introduced into the blood through the lacteals, or through the branches of the portal vein. It cannot, however, be doubted, that when the nutritious matter is first absorbed, it is in the liquid state. It is remarkable, therefore, that it should be found afterwards in the blood as a precipitate, or in the solid state. It may, however, be readily conceived how this effect will be produced, when we reflect that the food if dissolved in the stomach by an acid liquid which is absorbed by the vein of the stomach will, on mingling with the blood, be at once rendered alkaline, and will therefore let fall whatever substances its acidity enabled it to dissolve. This reasoning, however, is no longer applicable if we suppose the white matter of the blood to be derived from the admixture with it of the alkaline chyle. A different explanation has been suggested. It is supposed that the white matter of the serum might be soluble in it at blood-heat, just as the muriate of ammonia and other sediments which often appear in the urine upon cooling, are held in solution at the natural heat of the body. On trying the effect of artificial heat it was found that the serum became considerably clearer, but it was still opaque.—*Proceedings of the Philosophical Society of Glasgow*, Vol. I. p. 231.

A specimen of the white matter separated by the action of common salt and the filter, but too minute in quantity to admit of a satisfactory analysis, was found to be quite insoluble in ether and alcohol, while it dissolved in caustic potash. On boiling it in a solution of sugar of lead, it gave traces of black sulphuret. The conclusion is, therefore, that it contained no fixed oil, and consisted most probably of a *protein compound* like white of egg or muscle.

A further opportunity was afforded of examining the chemical qualities of this serum in some specimens obtained for illustration.

A man about thirty years of age, after fasting eighteen hours, dined upon twenty-four oz. of a pudding, consisting of two parts wheaten flour and one part suet, seasoned with salt. Two oz. of blood taken before the meal yielded a perfectly limpid serum. Seven ounces were taken three hours after the meal and the same quantity six hours after it. The serum from the former was like syrup, but a little white; that from the latter was milk-white. The white matter in the latter was separated by means of salt and the filter, and appeared similar to the substance before examined. It contained no fixed oil. The other specimen of serum threw up its cream spontaneously. It left upon the filter only a trace of white matter, but a notable proportion of a fixed oil, which was easily demonstrated by merely drying the filtering paper and holding it between the eye and the light. It can scarcely be doubted that this oil was derived from the suet of the pudding, while the white proteinaceous substance most probably represented the gluten of the flour. Thus two of the three elements of which the food consisted were found in the blood; but the starch, the most abundant of all, was sought for in vain.

It was subsequently found, however, that all blood ferments with yeast; hence it is possible that the starch is converted into sugar and thus reaches the blood in solution.

Objections to the Muriatic-Acid Theory of Digestion.—It has already been stated that objections have been urged against the idea that muriatic acid exists in a free state in the stomach. The experiment upon which the theory is built is an ambiguous one, and requires some elucidation. The experiments made by Blondlot are completely opposed to the muriatic-acid theory, and, if they should prove to be accurate, will produce material changes in reference to our views of digestion. They are so important, that we shall give a short view of their nature.

Blondlot distilled in the water bath 3878 grains of the gastric juice as pure as possible. The juice was collected from dogs, a quarter of an hour after giving them beef to eat, and it was deprived of the mucus and other foreign matter by two filtrations. The distillation was performed with the greatest precautions in a tubulated glass retort, to which a receiver previously washed with distilled water was adapted. The heat was continued until $\frac{4}{5}$ of the fluid had passed into the receiver, which required about 24 hours. The product was colourless—clear and limpid like water: it had no decided taste, but it possessed a characteristic smell—it had no action on red or blue turnsol, however long it was kept in contact with it. The *residue* appeared at first slightly turbid; but after standing, during which it deposited a few flocks, which appeared to be coagulated mucus, it acquired perfect transparency. Its colour was reddish-brown—its smell was empyreumatic, its taste strongly salt and acid, and it reddened turnsol paper slightly, so that it was evident that the residue contained all the acid of the juice four times concentrated. This residue was distilled to dryness, which required several days. The product in every respect resembled the preceding, and had no action on test paper. The solid residue, 775 grains in weight in this case, soon began to attract moisture from the atmosphere, and to be converted into a soft matter of a blackish-brown colour; its odour was that of most extractive substances, its taste strongly salt and acid.

Blondlot repeated this important experiment several times with precisely the same results in each case. He considers that the distillation ought to be performed slowly, otherwise the distilled fluid may carry over some common salt or muriate of ammonia. To distill the quantity mentioned, he required 4 or 5 days. He concludes that neither acetic nor muriatic acid exists in a free state in the stomach. He found that on attempting to neutralise the fluid with chalk, there was no effervescence; while the liquor retained all its acidity even after allowing the chalk to remain some days in contact with it. He then suspected the acidity to be due to phosphoric acid. He found that when chalk is added to phosphoric acid, till all effervescence ceases, the solution is still acid, which it does not lose even by long boiling; and this, he says, is the only acid which so acts with chalk.

To determine this more accurately, he made the following experiments:—Having placed a quantity of gastric juice in a glass, he added a few drops of sulphuric acid. In two or three minutes, an abundant white precipitate fell, which when examined proved to be sulphate of lime. By *oxalic acid* a white precipitate fell, which when calcined on a plate of platinum left quicklime. Abundant precipitates were produced by *potash, soda,* and *ammonia;* by *lime water,* still more abundant precipitates. Each of these precipitates, when collected, was found to be neutral phosphate of lime.

A quantity having been dried and ignited, left a small portion of a grey cinder, not deliquescent, which was digested in water. The solution was not acid, did not precipitate on adding ammonia or nitrate of silver; the residue dissolved without effervescence in muriatic acid, forming chloride of calcium; proving that this ash consisted almost exclusively of neutral phosphate of lime, the excess of phosphoric acid having been decomposed by the charcoal of the organic matter and the other salts. From these facts he concludes, that the acidity of the gastric juice is due to *acid phosphate of lime,* or *biphosphate of lime.*

When the juice is evaporated and digested in strong alcohol, the solution deposits common salt and also plates of salmiac, mixed with a little phosphate of soda and ammonia, produced probably by the influence of heat upon the common salt, and a little acid phosphate of ammonia. The latter he supposes probably to exist in the juice, of which he gives the composition as follows:—

	Water,	99·
Salts.	Acid phosphate of lime,	1·
	Acid phosphate of ammonia,	
	Common salt,	
Organic.	Aromatic principle,	
	Mucus,	
	Peculiar matter,	

In this table there is no mention of vegetable matter, showing that his experiments had been made only with animal substances.

Gastric juice is neutralized by carbonates and bicarbonates of potash, soda, and ammonia, the neutral phosphate of lime being precipitated. The same effect is produced by the neutral and alkaline subphosphates, except in the absence of effervescence. Quick-lime neutralizes the acidity with precipitation of neutral phosphate and disengagement of ammonia. When the food has been converted into chyme by the gastric juice, it is pushed forward by the contractions of the stomach into the duodenum, the first portion of the small intestines, into which the pancreatic juice as well as the contents of the gall bladder are poured. Here, therefore, the chyme is mixed with the bile and the pancreatic juice. Its acidity now gradually disappears. By the contractions of the successive portions of the intestines, it is steadily propelled along. During this course it separates by degrees into chyle, which is absorbed by the lacteals; and into the innutritious and indigestible matter, which is carried onward along the intestinal canal.

The chyle is to be regarded as blood in an early stage of formation. As it is mixed with the blood just before its entrance into the lungs, and as it never can be recognized after the blood has emerged from that organ, it is probable that it undergoes some vital change here which completes its assimilation, but of the nature of this change we are ignorant.

In conclusion, it is important to bear in mind, that the whole process of digestion, although perfectly uninfluenced by any voluntary act of the mind, yet is materially affected by mental emotions and sensations, and that the secretion of gastric juice by the stomach appears to be very remarkably under such influence.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXIII.

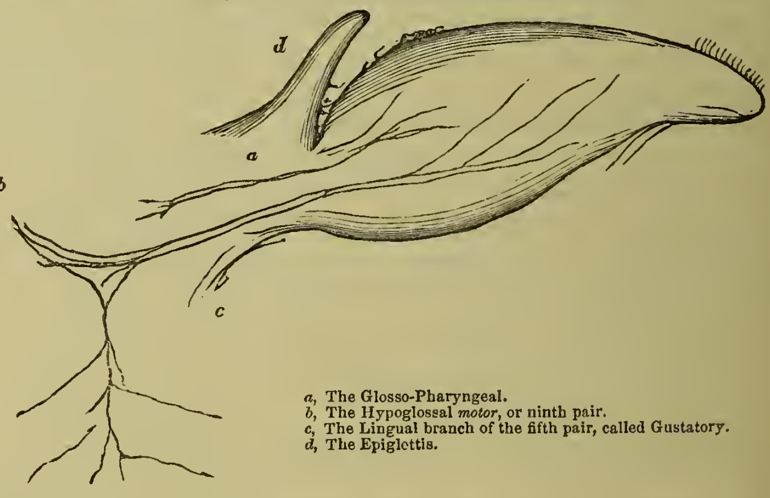
ON THE FACULTIES OF SENSATION AND PERCEPTION.—ORGAN OF TASTE.

The sense of taste is described to be that which results from the contact of certain substances, termed sapid, upon the tongue, gums, and palate. It is, however, dependent on common sensation, along with that of smell produced by the odour arising from many bodies.

The uses of taste, besides its being a source of enjoyment, are to excite the flow of the saliva and mucus which are to prepare the food for the stomach, and to inform us of qualities in the objects which excite it, which bear a certain relation to their salubrity and digestibility. This latter use is better exemplified in animals than in the human species, although in man, during sickness, it is generally a very safe guide.

The structure of the tongue, the principal organ of taste, presents stronger analogies with that of the skin than any other organ. Its minute anatomy need not be dwelt on here. The accompanying figure will give the reader a sufficiently accurate idea of the larger muscles and nerves composing the bulk of the organ. By consulting the note containing the explanation of fig. 1, he will readily enough understand the general form of the organ, and its connections. The whole tongue is extremely mobile in every sense; and the strong and large muscles enumerated below connect it with the lower jaw and hyoid bones. These are also called, from this circumstance, lingual bones, from *lingua*, the tongue. These muscles enter deeply into its composition; but there are also numerous layers of muscles which may be called *intrinsic*, because they do not go to or come from any other part, but are limited solely to the tongue. By means of these the tongue may be elongated, and even be made to protrude from the mouth; again withdrawn and forced to strike against the teeth and palate; or sweep the inside of

Fig. 1.
Diagram of the Nerves supplying the Human Tongue.



a, The Glosso-Pharyngeal.
b, The Hypoglossal *motor*, or ninth pair.
c, The Lingual branch of the fifth pair, called Gustatory.
d, The Epiglottis.

the mouth, or passed up between the cheek and jaws. The epiglottis, or covering of the air-passages, follows the movements of the tongue; hence the danger of keeping the tongue protruded from the mouth, and at the same time attempting to swallow food or drink, or indeed any body whatever. All the upper and a portion of the lower surface, together with the sides of the tongue, is invested in man, and of course in animals resembling him generally, with a reflexion of the common integuments of the body, or at least with a prolongation of what is called the mucous membrane. On the surface may be seen a number of projecting points, called papillæ, which, like all the rest of the surface, is covered with *epithelium* or scarf-skin. The fur covering the tongue in fevers and other disorders, is probably an altered and vitiated secretion of this epidermis, secreted of course by the subjacent vascular layers. When rubbed entirely off at any point, the papillæ are found to be most acutely sensible. Beneath this epithelium is the *pigmentum*, and the lingual rete-mucosum, as in other parts of the skin. The pigment is not visible in man, but is evident in the tongues of many animals: these parts are epidermic, and of course

extra-vascular and squamous. Beneath these epidermic parts is found the chorion or true skin, and into this a great number of muscular fibres are inserted on its deep surface; whilst on the other surface, immediately covered by the epidermic parts, numerous *nervous papillæ* project, almost forming a continuous layer, which, however, cannot be separated distinctly from the chorion. These papillæ are vascular and nervous, and probably form the true gustatory part. They are differently arranged, and seem even to have different forms in different animals; in man, they have been arranged as follows:—1st, The large or caliciform papillæ towards the base of the tongue; 2d, The conical; 3d, The tenticular; 4th, The filiform. These may all have different functions; but this is a point not well understood. The nerves of the tongue are three on each side, and they are of great size. The ninth pair of nerves supplies its muscles, and a large branch of the fifth pair, and a division of the glosso-pharyngeal, are also distributed chiefly to its surfaces. The glosso-pharyngeal nerve—we mean, of course, its lingual portion—is distributed chiefly to the surface at the base of the tongue; the fifth pair towards the apex; the ninth pair to the muscles throughout. An injury done the ninth pair, has been known to destroy the muscular power of the tongue, without affecting its sensibility or its gustatory powers.

The cavity of the mouth in which the tongue is placed, communicates at most times with another cavity placed immediately behind it, called the pharynx; but the orifice of communication may be, and is frequently closed by the descent of the soft palate, and elevation of the base of the tongue. The muscular action effecting this takes place generally involuntarily, or, as it may be termed, instinctively; and hence the occasional necessity for depressing the tongue with the handle of a spoon, or such other body, when we are desirous of examining into the state of the cavity beyond it. Large portions of the tongue have been removed without much interfering with speech or deglutition. A deep wound at the base of the tongue is always dangerous, and but too often fatal.

In the centre of the tongue is a palate or layer of a peculiar elastic substance, analogous to what we find in the back of the neck of sheep, oxen, and horses; and two large arteries supply the substance of the tongue with blood. Corresponding veins return the blood from these arteries.

The frenum, or bridle of the tongue, is a fold of membrane binding down a portion of the inferior surface of the tongue, but leaving the apex free. When too short in newborn children, it requires being divided by the surgeon. The operation ought to be performed with great caution; and, moreover, it is seldom requisite.

We have alluded above to the free though occasionally interrupted communication between the mouth and the cavity placed behind it—namely, the bag of the pharynx. By this aperture in man, air passes as readily to the windpipe and lungs as it does by the nostrils. It would seem, however, that in some animals, as in the horse, the passage of communication is not equally free, and is only fully opened when the food and drink are pressing from the one cavity to the other, it being generally understood that the horse cannot breathe by the mouth: he attempts it, however, when distressed, but probably without much real benefit. In like manner, it is almost certain that neither the elephant nor whales generally can ever, under any circumstances, breathe by the mouth.

The tongue, whose anatomy we have just described, is admitted by all to be the organ of taste. According to most physiologists, it is even perhaps still maintained to be the only part capable of perceiving the sapid qualities of bodies, this power being denied by them to any other part of the mouth. The phreno-mesmerist himself has not yet ventured to assert that an infusion of quassia may be distinguished from sugar and water by the extremities of our fingers or toes. The experiments of the ingenious and accurate Weber led to the conclusion, that neither in the palate, nor in any other part of the mouth, is there any perception of taste. It is possible, however, that, in this respect, different persons are differently constituted; and it would appear that some individuals do really possess a power of tasting with the soft palate or uvula, and even with the ceiling of the mouth or hard palate. Again, much disputation has been held in regard to the portion of the tongue itself which may be supposed the most gifted with the perceptive gustatory powers; nor is this an idle question, seeing that it has a reference to the distribution of the nerves of the tongue, whose general course has been already described. The hypoglossal, or great lingual nerves, are now universally admitted to be the nerves of motion of the tongue; but whilst the branch of the fifth pair is considered by some as the proper gustatory nerve, others claim this function for the glosso-pharyngeal (see the figure); and others think that both nerves may be required, or that both are essential for a right perception of sapid bodies. The reader is here reminded, that three distinct nerves proceed on either side into the tongue—namely, the ninth pair, or hypoglossal; a large branch of the fifth pair; and a division of the eighth pair, called the glosso-pharyngeus, from its supplying, in part at least, both the tongue and the bag of the pharynx, that cavity into which the food is received from the mouth, and which is in fact placed between the mouth and the gullet. The difficulty with regard to these nerves is this: if the branch of the fifth pair, which supplies the tongue, be a nerve of special sensation, it would require to be shown especially how this happens, seeing that the other branches of the same pair of nerves are merely nerves of common sensation. The same remark applies in some measure to the glosso-pharyngeal.

Comparative anatomy does not furnish data to solve these questions. The tongue of birds, it is said, receives no branches from the fifth pair; yet the swan and the parrot are said to taste acutely. Most birds, however, seem to be extremely deficient in taste, the duck especially; but it might not be correct to say, that even in them the sense is wholly wanting. A strong epithelial or epidermic layer, and even spires, protect the surface of the tongue in many animals; structures by no means adapted to fit it for a delicate organ of special sensation, or to improve its qualifications in this respect. But at the same time it is to be remembered that in many animals, as the chameleon, the ant-eater, the giraffe, and even, perhaps, the ox, the tongue serves as an instrument of prehension, as well as of taste.

Cruel and but too frequently unnecessary experiments on living animals have shown that, by cutting across in the living animal one pair of nerves supplying the tongue, the motions of the tongue cease; but this class of experimenters (for the honour of humanity, it is pleasing to think that it is not a numerous class) are by no means agreed as to the effects which follow a section in the living animal of the other nerves supplying the tongue. Paniaza, one of the most minute anatomists, able surgeons, and distinguished physiologists of modern times, attempted thus to solve the question in regard to the functions of that nerve we call the glosso-pharyngeal; but it may be said that he failed. Some excellent observers are still opposed to his views.

The loss of the power of taste is rare, but it sometimes happens. It is undoubtedly a great misfortune. We have known persons so affected terminate their career by suicide. The coincidence, however, may have been purely accidental.

Mechanical and galvanic stimulants applied to the tongue excite vague sensations, which no doubt, however, bear some analogy to sensations of taste. Again, many experiments have been made to determine what portions of the tongue are best endowed with gustatory properties; and it seems generally agreed, that the lower surface of the tongue, and the back part of the upper surface, are best endowed with such properties. Few persons can taste with the point of the tongue. The anterior half of the upper surface of the tongue is scarcely, if at all, equal to the perception of sapid bodies; and it has even been observed that certain substances give different sensations when applied to different

parts of the tongue. What is called the *after-smack,* seems to be of a compound nature, derived from various sources.

Taste is susceptible of education to a certain extent, as in the instance of wine and tea tasters. And there is even a sort of harmony in tastes, as well as in tones and colours. But different bodies must not be tasted too rapidly, else all power of discrimination ceases: and as regards the metaphysical history of the function, it may be said that the perceptions derived from it are much more objective, and less of a subjective nature than those of the higher organs of sight and hearing; or in other words, false sensations, sensations arising in the tongue and brain when no sapid body is present to excite them, are extremely rare when compared with the frequency of visual and auditory spectra. Their possible occurrence has even been doubted.

In the first part of this article on the sense and organ of taste, it has been shown how completely the tongue is a muscular organ, endowed with the utmost *mobility,* and also with common *sensibility.* It is therefore an instrument, and no doubt the chief instrument of speech; and with it the properties of bodies may to a certain extent be detected; for the determining of these, however, the fingers are by far the more appropriate instruments. The author of this article suggested, many years ago, to Sir Charles Bell, that the tongue of man was by no means so accurate a *tactile* organ as the fingers, although it might be so in some animals; and he instanced the fact that the pulse of the wrist could not in general be perceived by the tongue being applied over the artery, or at least only in an extremely obscure way, and that the number of pulsations could not be determined by the application of the tongue. By pressing, however, very strongly with the tongue against a very prominent artery, the pulsations of the heart may be counted and the thrill of blood in the vessel becomes evident. This does not, however, affect the main physiological proposition implied in the above remark, namely, that it is the presence of the skeleton in the finger which enables us to detect so readily with it the varieties in the number, force, and regularity of the pulsations of the heart as detected in the arteries; and that in the tongue of man it is the absence of any hard parts which unfits it in this respect as a tactile organ. The tongue of birds, therefore, may be an excellent tactile though an imperfect tasting organ. To resume, the conditions for the perception of taste in a sapid body seem to be, 1st, the presence of a nerve, with special endowments. 2d, The irritation of this nerve by the sapid matters. 3d, The solution of these matters in the secretions of the organ of taste. A calm investigation of all the facts shows that in regard to the special functions of particular nerves supplying the organ, a single well-observed, properly described case of disease in man is of infinitely more value than all the cruel and absolutely unnecessary and therefore brutal experiments performed on living animals specifically distinct from man. "The pressure of a tumour or swelling on the divisions of the fifth pair of nerves, caused loss of taste in the corresponding half of the tongue." This does not, it is true, prove that the nerve implicated is the sole and only nerve of taste; but it proves that if the glosso-pharyngeal be the nerve, it cannot act an independent part, but requires the aid of the fifth.*

The varieties in the sensation of taste are less understood than in the case of sounds and colours. The theoretical terms of taste, then, are unknown, a statement which we hope will please the taste of those who are constantly declaiming against *theory,* giving a preference to what they are pleased to call *facts.* And it is consoling at the same time to know that there exists nothing in the facts more absolutely at variance with the usually received physiology of the nervous system.

We had almost forgot to add that the tongue is liable to many diseases, some of which require the bold and firm interference of the surgeon. Bleeding caused by an injury to the tongue is occasionally restrained with difficulty, requiring at times the application of the actual cautery or red-hot iron. To malformation of the organ some surgeons have been disposed to ascribe the impediment of speech called stammering; and some very cruel and extremely improper operations have been performed by Dieffenbach and others, with a view to a removal of the complaint. Such operations are not warrantable; and the operators, whoever they are, forget a great principle, which ought to regulate all surgeons,—namely, that an operation is not to be performed merely because it can be done, but rather because it is advisable and prudent to perform it under existing circumstances.

II.—Of the Organ of Smell.

The term nose, as it is used in ordinary language, does not include all the structures required for the apparatus of smell. The more important, and indeed the more essential parts, as in the case of the ear, are placed more deeply in a cavity formed within the bones of the face, above the organ of taste and at the entrance of the air passages. It is a double organ, or composed of two cavities quite distinct from each other.

The *nose,* or the external visible part, varies infinitely as to its form, particularly amongst the inhabitants of England and the Lowlands of Scotland. This so great variety arises no doubt from the commingling of so many races of men in these countries. It does not seem to me, however, that we meet with the same variety in the form of the nose amongst the purer races. In the negro, for example, or the Jew, or even the Irish Celt, there does not exist that extraordinary diversity of form in the shape of the nose which is met with among the English and Lowland Scotch. There is then a certain form of nose peculiar to each race, which admits only of a limited range as to its varieties. In the Jew I have observed but three varieties as to the form of the nose, and these are but slight modifications of what may be called the primitive form of the race. The finest form of the organ occurs in certain young persons of the Jewish race; and the same form precisely is to be seen in the head of the young Memnon, a granite bust of extraordinary beauty brought from Egypt and now in the British Museum. This was probably the form of nose common to most ancient Egyptians. On the other hand, the ancient Greeks (I mean, of the classic age) were beyond all doubt a mixed race, composed of Phœnician, Egyptian, Armenian, Saxon, and Celtic blood. Hence the infinite variety in their physiognomy. What is usually termed "the Greek nose" and Grecian profile, does not seem to be so common in Greece as some have supposed. Finally, this profile and form of nose is sufficiently common amongst the Saxon race, from whom, probably, it was derived. The origin of the Roman nose is not well understood, but evidently it has not been derived from any *Celtic race.*

In the nose, anatomists describe the summit or root, the *dorsum* or ridge, the *lobe,* and the base. In the base are the nostrils, bounded externally by the alæ or wings.

Moreover, the nose is composed of a skeleton or framework and of certain muscles; internally, it is lined with a mucous membrane; blood vessels, nerves, and lymphatics are found here as elsewhere; the common integuments invest the outer surface. This portion of skin has its peculiar sympathies.

Two bones, whose shape will be best understood by looking at figure 2, support the part we now speak of; their function is best judged of by observing what happens when by accident or disease they have been lost. The cartilages which assist in forming the nose, are the two *lateral* cartilages, the two outer cartilages; and to these may be added the great cartilage of the septum or middle division of the nostrils. Thus modern anatomists describe five cartilages in the nose. Santorini, an Italian anatomist, on the other hand, with the minuteness peculiar to the Italian character, described *eleven* cartilages, of which five may be said to be fully developed,

* If it be true that the tongue may lose its *common sensibility,* and yet preserve its power of taste, this would show the uses of the fifth pair to be more complex than are generally supposed.

and six have been left by nature in a rudimentary state. Santorini, no doubt, was correct; and the view he took of the matter was not only the most philosophic, but in point of fact the only true view. These small nodules of cartilages, which in men are so imperfect, represent more fully developed cartilages in other animals. It is not in man that we are to look for the fully-developed apparatus of the nostrils.

A fibrous membrane connects all these cartilages to each other and to the adjoining bones. In fig. 2, *a a* show the form of the lateral cartilages; *b b* mark the cartilages of the wings, or alæ of the nose; and *e e*, the smaller rudimentary cartilages described by Santorini. The cartilage of the septum will be best understood by inspecting fig. 3. Aided by a bony plate descending from a bone termed ethmoid, this large and

Fig. 2.

n n Bones of the noso.
a a Lateral cartilages.
b b Cartilages of the wings.
e e Cartilages of Santorini.

Fig. 3.

a, The bony plate of the ethmoid.

b, The middle cartilage of the nose.

c, The vomer bone.

d, The hard palate.

important cartilage, the free margin of which may be seen between the nostrils, and whose loss even partially is so much felt by those to whom this misfortune has happened, divides the nostrils from each other; it is in fact the septum or partition wall.

The muscles acting on these cartilages have not yet been very accurately or minutely described; nor perhaps the nerves, which of course are distributed to these muscles. A partial view of them will be found in a preceding number. The fact which may perhaps most interest the reader is the obvious connection these muscles have with the respiratory or breathing system. The first act probably of the respiratory movement is to expand the nostrils; and the actual condition of the lungs may occasionally be judged of by the state of the nostrils and by the action of their muscles. The cartilages just described seem naturally to close the nostrils even in man at all times when not acted on by their muscles. In this respect, however, they are probably more perfect in the seal than in man; in the rorguel or great northern whale they are the most perfect. In this animal, cartilages which no doubt correspond by analogy with the lateral cartilages in man, project deeply into the nostrils on either side. Each is nearly as large as a bolster. By their extraordinary size and elasticity they plug up the nostrils, completely protecting them from any eruption of the waters of the ocean when the rorguel seeks its lowest depths; but when on the surface and at the breathing moment, large muscles, fixed by one extremity into the centre of these cartilages, and by the other to the bones of the face, acting simultaneously with the midriff and other breathing muscles, suddenly withdraw them more or less completely from the nostrils, thus clearing a wide passage for the descent of air into the lungs. So soon as this action ceases the cartilages return by their own elasticity into the nostrils. There is no mechanism connected with animal structures more wonderful than the one just described; and it is singularly wonderful and yet mysterious to observe how nature has employed, in this great respiratory act, similar materials throughout the whole range of the mammalia. The mechanism by which the nostrils are expanded in man is precisely similar to that in the rorguel; and the structures which to the mere matter of fact observer appear so different, are yet essentially the same and strictly analogous. Let us return, however, to man. The human structure is incomparably the most interesting to be known of all animals, although it may be readily conceded that a full knowledge of the uses of man's organs cannot be rightly attained without an occasional appeal to comparative anatomy.

The skin of the upper part of the nose differs evidently from that of the lobe and lower parts; this latter is extremely firm, and crepitates when cut; the sebaceous follicles are remarkably developed.

The interior of the nostrils is usually shown by two sections, given in figures 4 and 5; these figures expose the course of the lining membrane of the nose, usually called Pituitary or Schriedenium. Fig. 4 represents the outer

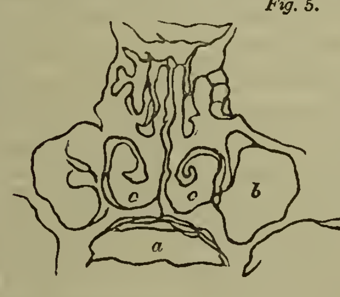
Fig. 4.

b, the middle turbinated bones, cut partly away.

a, the lower turbinated bones.

wall of the right nostril. The vascular membrane covers the whole of these surfaces. Where first seen at the edge of the nostrils, it is intimately united to, and may be considered continuous with, the skin. Inwardly, it is prolonged to the middle ear and downwards towards the gullet and windpipe; it is extended, moreover, although modified into various bony cavities existing in the bones of the face and cranium, whose uses are far from being well understood. The orifices of some of these may be seen in the figure; the remarkable rolled-up structures are the lower and middle turbinated bones; these are also covered with the pituitary membrane, and by being so rolled up are presumed to offer a more extensive surface for sensation than would have been otherwise obtained in so confined a space. Certain it is that the sense of smell is always very strongly developed when these turbinated bones are found large and much rolled on themselves. It is upon this surface that the nasal tube opens, conveying the tears from the surface of the eyes into the nostrils. Fig. 5 presents an interesting view of both nostrils

Fig. 5.



a, palate.
b, sinuses or cavities in the cheek bones.
c, *c*, lower turbinated bones, cut across.

cut perpendicularly down about the middle; it may be readily enough understood by simply looking at the middle partition separating one nostril from the other.

The pituitary membrane is very vascular and is apt to bleed excessively from constitutional and other causes; the arteries are very numerous, and so likewise are the veins. Hence the great advantages to be derived occasionally by applying a leech or two to this membrane in deep inflammations of the nose; the plugging of the nostrils on the other

hand, to stop bleeding, is often a troublesome operation. Excrescences or polypi of various kinds grow from this membrane, and so, more or less completely interrupting the nasal passages, affect the breathing ; these should be removed by a skilful and careful surgeon. Lastly, two kinds of nerves at least are distributed to this membrane ; first, the *olfactory* or first pair of cerebral nerves ; secondly, a branch from the fifth pair of cerebral nerves. Nearly all agree that the first are properly speaking the true *olfactory* nerves. The branch from the fifth is supposed to bestow on the membrane the common sensibility which with other parts of the body it requires. There are difficulties, however, in adopting this simple view of the physiology of these nerves, which we shall state in the next section. We shall now briefly give the history of the physiology of this sense.

"The sense of smell takes cognizance of the particles of odorous bodies which are held suspended or dissolved in the air." This is the definition of most physiologists ; but the term "or in water" must be added, if we propose including fishes amongst those animals which have the power of smell. It is generally understood and admitted that the odorous particles are perceived by the *olfactory* or first pair of nerves, although, as we shall afterwards find, a branch of another pair of nerves, the fifth, is also required to fit the organ for the exercise of its function. The *olfactory* nerve is presumed to be distributed extensively on the mucous membrane investing the deeper cavities of the nostrils.

There can be no doubt that all analogy is in favour of the idea that the olfactory nerves are truly what their name implies them to be ; yet cases occur in which an injury done to that small branch of the fifth distributed to the mucous membrane and lobe of the nose has completely destroyed the power of smell. Such pathological cases present great difficulties, and are in a great measure as yet inexplicable by any physiological theory, like many of the beautiful views of Sir Charles Bell and Mr Walker, for example, in regard to the nervous system.

It has not been proved satisfactorily that fishes smell, and yet they have very large olfactory nerves. Birds also have but imperfect olfactory organs ; in them the first pair of nerves is small. The vulture, which was long thought to discover his prey by the sense of smell, has been proved to possess this power in an extremely limited degree, and so of other birds. On the other hand, it is probable that some hot-blooded animals of the order Cetacea, as the well-known porpoise, have olfactory nerves so small, that many anatomists doubt their existence; and from this it is fair to presume, that such animals smell very imperfectly, if at all. This remark, however, does not apply to all Cetacea, the rorguel or piked whale having an olfactory nerve as large, proportionally, as man himself. But it is in the horse, ox, deer, &c. that the sense of smell appears to be most highly developed ; by this sense, the horse declines not unfrequently to taste water which to man's senses would appear to be pure ; by it also he would seem to discover in the open field the approach of enemies or friends. On the unenclosed fields of the Cape of Good Hope, the farmers' horses are turned out to graze and in some measure to shift for themselves, being altogether without protection from man. It may be owing to this that they exhibit instincts and a sagacity unexpected and occasionally remarkable. They collect in circular groups on the approach of danger, the mares and younger horses occupying the centre, whilst a stallion or gelding leaves the party and gallops towards the suspected object. As he approaches the object of his fear or rather suspicion, (for if a stallion he seldom shows fear,) it is curious to observe how he, by a long circuit, places the person or animal between him and the point whence the wind blows, however slight the current of air may be ; or, in other words, how he almost uniformly prefers exercising the organ of smell to that of sight. Another circumstance worthy of notice in regard to this organ is that the antelope, zebra, quagge, and wildebeest orgnoo, frequenting in countless numbers the vast grassy plains and mountains of Southern Africa, do uniformly, when pursued by the huntsman, gallop up towards the quarter from whence the wind blows; and African farmers have often pointed out to me the curious fact, that oxen, when turned out to graze on the unenclosed field or desert, do very generally, if not uniformly, graze towards the same quarter, as if desirous of ascertaining whilst feeding, by means of the organ of smell, the approach of any dangerous or suspected object. In the pursuit of the young quagge, zebra, or antelope, it is sufficient merely to press the hand several times over its nostrils when it is overtaken, as on being let loose it will follow the huntsman into bondage, even although its parents may be seen free at no great distance and the liberty of flight freely permitted it.

The power of smell in the dog and pig need not to be adverted to, as being so well known. That of the elephant is probably extremely acute.

The power of smell and even its character vary much in different persons. Females generally prefer perfumes and sweet smells; flowers are generally agreeable to them on this account. The sense of smell is extremely acute in some persons, and is not impaired by a residence amongst unpleasant odours.

PRINCIPLES OF ALGEBRA.

CHAPTER VII.

Of Simple Equations containing more than one Unknown Quantity.

66. Suppose that there exist *simultaneously* two such equations as

$$x + y = 15 \qquad x - y = 7$$

in which we have two unknown quantities, x and y, and two independent conditions expressed regarding them. It is here obvious that the single condition of either of these equations is not sufficient to fix the value of the quantities ; it connects them, nevertheless, in such a way, that if one can be found, the other can be found also. Taken separately, the equations are therefore *indeterminate*, or admit of an indefinite number of solutions: for the first will manifestly be satisfied by any pair of numbers whose sum is 15, and the second by any pair of numbers whose difference is 7. The following are instances :—

Solutions of the first.		Solutions of the second.	
$x = 12$	$y = 3$	$x = 12$	$y = 5$
$x = 11\frac{1}{2}$	$y = 3\frac{1}{2}$	$x = 11\frac{1}{2}$	$y = 4\frac{1}{2}$
$x = 11$	$y = 4$	$x = 11$	$y = 4$
$x = 10\frac{1}{4}$	$y = 4\frac{3}{4}$	$x = 10\frac{3}{4}$	$y = 3\frac{3}{4}$

and so on for as many pairs of numbers as we please. But the solution required here consists in finding a set of values for x and y, which shall simultaneously satisfy both equations. Such a solution is contained among the preceding instances, where we find a set of values, $x = 11$ and $y = 4$, which satisfies both equations at once.

A group of equations of this sort, in which we have the same number of equations and unknown quantities, is called a *system of simultaneous equations ;* and the first part of the process of solution consists in *eliminating* one of the unknown quantities ; that is, by some combination of the two equations to derive a new equation from which one of the unknown quantities shall be excluded. The following are the methods usually employed with equations involving two unknown quantities :—

67. First Method.—*By substitution.*—Find an expression for one of the unknown quantities from one of the equations, and substitute it for that unknown quantity in the other equation. The result will be an equation containing only one unknown quantity, and may therefore be solved by the methods already given.

Let the proposed equations be of the general forms *

$$a\,x + b\,y = c \qquad a'\,x + b'\,y = c'$$

* To avoid using many different letters, it is common to employ the same letter with one or more accents, to signify different numbers. Thus: The symbol a' differs as effectually from a as a does from b. As to the meaning of the numbers for which they stand, a' may be read "a" *accented*; but it is more commonly read "a" *dash*, though not so correctly. The same applies to b', c', or any other accented symbol.

as the currents circulating round each particle contained in the magnet, N S, revolve in planes at right angles to the axis of the magnet, their action must be *transverse* to that axis, and must induce a straight conducting wire, P M, also into a *transverse* position in relation to the axis, and to the magnet itself, in which position the current traversing the wire is parallel to the direction of the currents in the adjoining part of the magnet. This explanation of transversal action is grounded chiefly upon the assumption which Ampère subsequently proved by experiment, that every electric current tends to induce currents in the same direction in other bodies.

92. This theory, however, although extremely ingenious, and affording satisfactory explanations of the greater number of the phenomena, has, unfortunately, *not* succeeded in removing the difficulties which are created by the extraordinary circumstances attending the induction of magnetism by electrical currents traversing conducting bodies, which have been particularly referred to in paragraph 85, and which were first noticed by Savary. No hypothesis has as yet been promulgated, which satisfactorily explains the strange variations alluded to.

93. This chapter concludes that part of the science to which the term "electro-magnetism" *strictly* applies, although it has been customary to include, under the same head, the subject of electro-dynamics, or the mutual actions of electric currents moving in different directions. It is, however, our opinion, that this latter subject would be best treated under a distinct head, and as a distinct branch of electrical science. It is proposed, therefore, to devote a few chapters to the subjects of electro-dynamics, and magnetic and thermo-electricity, including a description of those voltaic and electro-magnetic instruments which appear most useful in modern research, and are most likely to advance future discovery.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXIV.

OF THE ORGAN OF HEARING IN MAN—ITS ANATOMY, PHYSIOLOGY, AND PATHOLOGY.

No one unacquainted with the mysterious structures revealed to us by anatomy, would ever have imagined or conjectured the singular form, the high complexity, the inexplicable arrangement of the parts composing the organ of hearing in man. The visible part, usually called the ear, performs but a very small share indeed in the performance of the functions of hearing, though of great beauty when well formed, and highly ornamental to the human head; but the functions or uses, even of the external ear, have not been made out; and much less do we comprehend the uses of the deeper parts, and of the middle ear, as it is called; of the labyrinth or internal ear; and of the appendages connected with the organ generally. But, before speaking of the presumed uses of these singular structures, let us place before the reader as brief an outline as may be of the anatomy of the organ of hearing.

Fig. 1 (see Plate), represents the human ear, in which *a* is the cartilage, or external ear; *b*, the auditory tube; *c*, the tympanum or drum of the ear; *d*, the cavity of the tympanum, kept filled with air by means of the eustachean tube, *e*, which comes from the back of the mouth. It is owing to slight congestion of this, that in a common cold we experience a little deafness. At *f* is seen a chain of four little bones; at *g* a cavity called the vestibule; at *h* three canals called the semicircular canals; and at *i*, the cochlea.

The vestibule, the cochlea, and semicircular canals constitute the labyrinth or internal ear, which is the true organ of hearing. The subjoined figure will give the reader some idea of the osseous shell shutting in the membranous and nervous structure found within the labyrinth. *a* is an opening called a fenestra, leading into the cavity of the vestibule; *b*, the semicircular canals; *c*, the cochlea. In order to

Fig. 1.

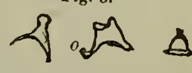
see the contents of these cavities, the external osseous wall must be filed off, and the same structures will then assume the appearance represented in the annexed figure. Into

Fig. 2.

the labyrinth passes the auditory nerve, by means of which, no doubt, the vibrations of the external air are conveyed in a mysterious manner to the brain, giving us the sensation and perception of sound.

But on the interior of this deep or internal ear, there is an apparatus of structures called the *middle ear*. This is also composed of three parts—namely, the tympanum, which is a cavity; the eustachean tube, which communicates with the throat; and the mastoid cells. In the cavity of the tympanum we find a membrane which also invests the other two divisions mentioned; and besides this membrane, there are four bones of the most singular construction, and named from their very forms, the hammer, the anvil, the orb-shaped bone, and the stirrup. *m*, the hammer; *a*, the anvil; *o*, the orbicular bone; *s*, the stirrup. These bones form a sort of chain, connecting the drum of the ear, which is situated exterior to them, and the vestibule, the base of the stirrup bone being placed within the opening called the fenestra ovalis, an opening which, we have already said, leads directly into the vestibule. The drum of the ear, on the other hand, against which the hammer bone rests, is a circular membrane of a peculiar structure, which may be made more or less tense by means of muscles acting on the chain of bones.

Fig. 3.



On the outer side of the drum of the ear is the membranous and cartilaginous tube which, extending outwards, terminates in the external or figured part of the ear, visible on the side of the head. If water or any liquid be injected into the external opening of the ear, it does not penetrate further than the drum of the ear, so long as that membrane remains healthy and entire. The drum may, however, be diseased and ulcerated; and it has been punctured by the surgeon for a peculiar form of deafness, and then air or tobacco smoke may be forced from the throat and made to appear at the external ear; but not otherwise. A more minute description of the organ would not much avail the reader in understanding the mere mechanism, nor would it enable him the better to comprehend the physiology of the organ. Here, as in many other organs of the body, we should never have discovered by mere anatomy alone the uses of the structures; of this curious fact, the brain and ear form striking *examples*.

By hearing, is meant, physiologically speaking, the distinguishing, appreciating, and perceiving the undulations or vibrations excited in matter, and communicated by means of

the auditory nerves to the brain. Pulsations of the air, water, or solid bodies, are communicated to the ultimate fibrils of these nerves, and the changes produced in them, extending to the brain, are perceived by us as sounds.

The external ear and its associated apparatus, may be considered as conductors of sound. It is quite certain, however, that the loss of the external ear has in numerous cases interfered in no shape with the accurate perception of sounds. On the other hand, the external ear in many animals, as the horse, ox, dog, &c., must perform the functions of a real acoustic tube. But we shall adhere chiefly to the ear of man throughout the following observations.

It is presumed that sounds pass usually along the external passage of the ear towards the drum of the ear, against which they impinge, and cause it to vibrate. This passage of the ear is unquestionably an important part in ordinary or normal hearing. A number of fine hairs grow within the tube; the walls are formed partly of the common integuments of the body reflected inwards. Even the scarf skin itself passes quite to the bottom of the tube, and is reflected entire over the drum of the ear. Besides this, a series of small glands exist here, whose office is to secrete the peculiar substance called the wax of the ear; a deficiency of this wax affects the utility of the organ very considerably; so also perhaps, a too great abundance of wax, or its altered qualities.

In eager listening, the mouth opens instinctively, and this has been supposed to widen the tube of the ear, by altering the position of the condyle of the lower jaw bone. The dullness of hearing in very young children has been ascribed to the natural narrowness of the auditory tube in them; but other causes, no doubt, contribute to this.

In dullness or loss of hearing, the remedial means within the power of the surgeon are nearly confined to the condition of this part of the organ, the external tube, and to the drum of the ear. For this reason, the most careful examination should always be made of these parts, even in those who have been *reputed* deaf from infancy, for in many cases the deafness may have come on merely during infancy, and may not have been congenital. I remember the case of a person who was reputed to have been deaf and dumb from his very earliest years, and no doubt he was in reality so; but on examining his ears after death, the tube in one was found filled with inspissated cerumen or wax, the pressure of which, apparently, on the drum, had caused a small opening to form in it; all other parts of this ear were quite sound, and of a healthy appearance; in the other ear, the external tube was filled with cerumen, the drum was lost, the lining membrane of the middle ear thickened and ulcerated, and the small bones bathed in purulent matter. Now, in this ear, the diseased state was probably beyond all remedy by art; but not so the other ear; whilst the condition of both showed, that with a due knowledge of the condition of the organ, and appropriate means, the hearing might have been restored.

The structures next to be considered, with reference to these functions, are the drum of the ear, and the chain of bones contained within the cavity of the tympanum. Now the difficulties multiply exceedingly, for it cannot, I think, be shown, especially as regards the four tympanic bones, that such structures and such arrangements have any known philosophical connection with the nature of sound. It is said that entire destruction of the drum of the ear by disease is always attended with deafness or loss of hearing; but physiologists of great eminence deny this statement. Even the presence of the chain of bones does not seem essential to the right performance of the function.

The uses of the eustachian tube, that is, the tube connecting the cavity of the middle ear with the throat, are supposed to be to establish static equilibrium between the air within the tympanum, and that of the external atmosphere. As it is liable to become obstructed, the practice of probing it has been much in use of late years; air also has been forcibly driven into it with a view to overcome obstructions.

OBSERVATIONS ON THE ADAPTATION OF PUBLIC BUILDINGS TO THE PROPAGATION OF SOUND, CONSISTENTLY WITH SPEECH.

By William Shand, Esq.

The following short observations are intended to show, by practical illustration, the difficulties that have been experienced in regard to the Economy of Speech in apartments, and also the rules and means by which this Economy may be effected.

General Remarks.—It is remarkable with what devoted assiduity men of science apply themselves to discover the cause of some peculiar phenomenon in nature, which, to many, appears of little importance, and may, by the rudest mechanic, be practically exhibited when the principles or laws by which it is produced are understood.

When it was discovered that the electric fluid acted by the external surfaces only of conducting bodies, to a superficial observer it seemed of little consequence, but much time and many experiments were necessary to determine this.

When Sir Humphrey Davy discovered what led to the formation of the safety-lamp, it appeared a trifling matter, but it cost that distinguished man of science much time and labour. The telescope, which brings so many distant worlds into view, is formed of bodies possessed of two simple properties—the opaque and pellucid—all else is artificial arrangement; and when optics was in its infancy, could it have been anticipated that this science would have been brought to such a height of perfection, and that many educated and able men would devote themselves solely to one department of it?

Much has been effected in the economy of heat, but it is applicable in such a variety of ways, and to so many purposes, that although much of utility is known, probably still more remains to be understood.

Difficulties in copying an erection consistently with Acoustic Principles.—The most subtle and abstruse phenomenon in the whole range of physical science is sound, which has hitherto been an *ignis fatuus.* In the very limited space of a common apartment, individuals are seen opening their mouths, stretching their necks, and putting the hand to the ear in order to catch that which is not, a false sound being to the ear what ocular deception is to the eye. All men fancy it to be within their reach—of this various instances are at present exhibited; and these remind us of a circumstance, related by several authorities, of some Jesuits who erected a building in imitation of one near Milan, where the sound of a pistol shot is repeated upwards of forty times; but although the copy was in appearance the same as the original, yet it was without an echo.

Desertion of Principles in copying Canon Mills, Edinburgh.—Canon Mills (a place intended for the preparation of gas), where the first General Assembly of the Free Church of Scotland met, is now considered a model for the economy of speech; and several places of worship have been erected as true acoustic copies of this edifice, which consists of, in part, an earthen floor, walls of rough solid masonry, and slates as they came from the quarry, affixed to wood as it left the saw, all being simple compact materials, with rugged exteriors, having little vibratory action or sound, *the solidity of the bodies and roughness of the surfaces* being the principles that are favourable to articulation by producing limited *undulations;* but the rough surfaces occasion harsh sound on the ear, in the ratio of their proximity to it.

In the copies from the original, instead of being partly earth, the floor is all boarded and hollow under, giving out much extraneous sound from the action of the feet and other causes. The walls, instead of being solid and rough, are lined with lath and plaster, hollow between, and smooth on the exterior, consequently having comparatively much more action and sound than the original; while the roof is lined with lath and plaster, in like manner as the walls; not anything being retained in the copies consistent with the properties of Canon Mills, except the general form, which is bad. All this deviation from the original seems strange, when it is considered that not a single atom in a sonorous body can be added or displaced, without influencing sound. It is also remarkable if an old building, intended for so foreign a purpose, and so rude, should be found more demon-

strative of the economy of speech than all the works of art that have been intended for this purpose.

Instance of the Class-room of a Man of Science, formed of similar materials, and producing similar Effects as in Canon Mills.—I shall now give another instance of rude and rugged materials producing similar effects, from similar causes, by moderation of action and sound. A celebrated physiologist, in his examination before the last Committee of the Commons, on the transmission of sound in apartments, &c., alludes to a particular class-room, as constructed on scientific principles, and well adapted to the purposes of speech. In it the floor is of earth, the walls of solid and rough masonry, the roof is of unplaned plank, covered above with a thick coat of compost, and supported in the central parts by pillars of brick, in their original porous state; all being comparatively solid, and rough on their exteriors. The only material difference that I can perceive is, that the old gas-house, Canon Mills, is a matter of chance in regard to sound; whereas the learned doctor's class-room has been constructed by a man of science; they are indeed very different in form, and yet form is the only point that architects seem to consider of importance in imitating Canon Mills. One advantage in both these places is, that *there is little glass exposed to the voice of a speaker.*

The materials used in Canon Mills, the physiologist's class-room, the meanest cottage, or even the barn, are alike.

Erroneous to suppose that Undulatory Action should be lengthened, and Reflections prolonged.—The learned doctor, in his further depositions, recommends tbat the reflections of speech, in the Houses of Parliament, should be taken from the ceilings, transversely to the direction in which the human voice proceeds from the mouth; *the direction being horizontal whether we sit or stand.* He also advises that the ceilings should be formed on the principles of a piano-forte sounding-board; thus increasing and prolonging sound and the reflection of each letter more decidedly than the copyists of Canon Mills.

It may now be proper to endeavour to ascertain the principles by which the reflecting bodies, in these two apartments, are less ungenial to articulation, than where such are more sonorous and refined in appearance, as this may lead to the beneficial use of materials possessing similar properties, but less offensive to the eye.

Reasons why Speech is less indistinct in Canon Mills and the Physiologist's Class-room than in more refined apartments.—Doctor Neil Arnot remarks, that when sound is reflected by a solid, the angle of incidence and reflection correspond; and he illustrates this by a boy's hand-ball thrown against a wall, when the angle of reflection is equal to that of incidence. But the analogy applies only in a limited degree, because the ball is kept together in mass, whereas, the component parts of the atmosphere are scattered and divided, and so is sound, as our sense of hearing tells us. The greatest repelling force is no doubt in one direction, but the matter that gives effect to sound passes, in a certain degree, in all directions; the particles in the atmosphere impinging on a rough surface, press in various directions, in conformity to the minute angles presented to them, and consequently occasion less vibratory and undulatory action in the reflecting body than when the surface is smooth and the pressure in one general direction. The component parts of the atmosphere, thus recoiling in various directions, strike upon and oppose each other, and from this cause also lessen sound. If the ear be near to such rough surfaces, tbey occasion harsh sound to be transmitted to the nerve of hearing; but at a little distance, the atmosphere again runs smooth, and produces no such effects.

I would next observe, as to the earthen floor, that the action and sound from it are much less than from hollow boarding—the earth is comparatively soft, little elastic, and rough externally—for these reasons, sound from it does not sensibly affect the ear, nor cause any reaction from the roof. These facts may be learned from the ground in general producing no confusion either in speech or music. The earth has also an action different from hard bodies of limited thickness, such as boards, lath, and plaster, by which motion and sound are lessened in these materials.

Angular Surfaces calculated to prevent extraneous Sounds from reaching the ear.—The apartments just alluded to are, I conceive, better calculated to demonstrate, by the rough surface and comparative solidity, the means by which harsb and ungenial reflections may be prevented from reaching the ear, than to exemplify the manner in which consistent reflections are to be obtained.

Sound reflected from Sonorous Solids in Apartments, in at least six directions, must necessarily confuse Speech.—It may be remarked, that an apartment for speech being a work of art, in which solids are in a limited space, and most of them sonorous, when from the human voice, or any other cause, sound is produced by rapidly agitating the atmosphere, it impinges on, and recoils from, the sonorous solids, on the walls, the floor, and the ceiling, in at least six different directions; and if the agitation be great, the effects are similar to what is produced in tbe ocean, when waves meet from various directions in a small compass, occasioning, by their conflict, confusion in sound, as it has already done in the atmosphere, by which it is conducted.

There are various ways of exemplifying this in apartments, and in the atmosphere, where sound is not confined.

All Curvatures, by concentration, confuse Speech.—Notwithstanding that all writers on this subject, so far as I have been able to ascertain, recommend excess of sound, and several advise its concentration, or being made to act in foci, wherever the human voice, in speech, acts within a curvature, articulation is deranged, and the greater the curve and the more sonorous the material, the greater is the perturbation.

The evil of extreme agitation, by changing the original character of sound, is exemplified in that of a bell, the sound of which is most clearly, intensely, and distantly heard, when there is an extremely light current of air moving from the bell towards the ear; but if the wind be strong, the component parts of tbe air are deranged, and sound is not heard so intensely, distinctly, or distantly.

Sonorous Solids conduct Sounds generally with velocity and intensity in a similar ratio, but in air it is equal in Velocity and Character throughout.—Sonorous solids are considered to conduct sound with velocity much in the ratio of the intensity with which it is produced—concrete plaster 11 or 12 times, and glass and fir wood with 15 or 16 times its velocity in common air. In the atmosphere it passes with equal velocity in all directions, if no more dense medium should intervene between the source of sound and the ear, and it is *conducted without change of character.* In solids, its character and direction are changed, and the degree of sound depends on the density of atoms, and their distance from each other. When sound reaches a solid, its direction and character are changed, from various causes, according to the nature and form of the solid. It is produced by cohesion, repulsion, and friction in the atoms, and the degree of sound is, therefore, in a great measure, dependent on the density of the atoms and their distance from each other; thus, silver and gold are less sonorous than copper, bell-metal, or glass; and lead, which is peculiarly soft, is less sonorous than any of these bodies.

Sound acts similarly in the Musical String and in Wood of long fibre.—There are other properties and arrangements in certain materials, which appear to operate, by their cohesive and repulsive principles, most powerfully in one direction; for instance, in wood of long fibre *it acts predominantly in the direction of the fibre, similarly to that in the musical string.*

Not only do tbese circumstances lead to a knowledge of the degree and character of sound emitted from various bodies, and tell us tbat every atom acts its part in producing it; but an understanding of all these points is necessary for the control and guidance of this singular pbenomenon.

Sound being produced in Solids, acts throughout all their atoms.—On striking a solid, so as to produce sound, every atom in it is set in motion, and if another sonorous solid be in contact witb it, similar effects are produced in tbe second as in the first solid, until by friction the atoms are brought to rest, when souud also ceases.

Predominating influence in the Solids, but air also necessary to produce Sound.—For the reasous given, in the solids* usual in apartments, sound operates with more intensity and rapidity than in the atmosphere alone (altbough the solid must be in contact witb air), but tbe predominating influence is in the solids.

It is evident, from these and other understood facts, that it is

* Professor Liebig says, that every atom in the earth has its own atmosphere, and every atom in the finest metal must have its own atmosphere to produce sound. He also remarks, that cork and india-rubber have done more than anything else, in the course of the last fifty years, for the improvement of chemistry; and such bodies as these, buff leather, and woollen cloth, may do much for the economy of sound.

in the solids in and surrounding an apartment, that sound must be regulated.

Cross Sounds not admissible, &c. Necessity of regulating Undulation in the Solids.—I have already explained that neither cross sounds nor excessive sound is admissible, and that reflections which reach the ear must fall on the pinna horizontally—that the undulatory motion in the reflecting bodies must be regulated; and I shall further demonstrate the means by which this is to be effected, and those by which cross sounds are to be withheld from the ear, without exposing soft non-sonorous materials, so as to arrest the tremulous atmosphere and sound generally in an apartment. I have certainly explained enough to convince the most sceptical that it is preposterous to imagine that all that is requisite to be attended to is the mere form of a room, or that materials may be thrown together indiscriminately, conducting and reflecting in various directions and in any degree. As sound passes with equal velocity in all directions in the atmosphere, the first solid that the voice of a speaker must operate on, is that nearest to him, and, being conducted with so much greater rapidity by the solids than in air, it must pass by the solids, and by these be given out to the atmosphere.

Effects of the predominating velocity and intensity of Action and Sound in the Solids.—For instance, supposing an apartment 85 feet in length, and half this width, and that the speaker is placed in one end against the wall, the sound of his voice passes by the atoms of the solids in the walls to the other end of the room when it is only a few feet from his mouth in air, and *as undulation succeeds undulation* with so much greater rapidity and intensity of effect in the solids than in air, the predominating influence must be in the solids.

Prevention of Echo insufficient to economise Speech.—Many suppose that preventing echo and a repetition of reflection is sufficient; but this is only a palliation of the evils experienced, because a single reflection, although it may be prolonged too much, is less prejudicial than a repetition of reflection.

For the reasons given, irregular reflections of the voice and extraneous sounds are so general that, although the ear may not be sensible of these individually, they interfere more than we are aware with those which convey distinct and intelligible sounds to the nerve and sense of hearing.

Further general observations.—In different phenomena, causes and effects vary; but, reasoning by analogy between hearing and sight, I would remark, in regard to the faculty of vision, that, if the eye be directed to two objects at the same time, perception is less in both than if concentrated on one object. Are not cross lights or rays approaching the eye in transverse directions prejudicial? and shall sound, without measure or adjustment, be communicated to the ear with impunity?

The circumstance alone of speaking without oppression and with ease in all places where the soft material has been used, is, of itself, very important, as many say they would rather speak a whole day in one place, than two hours in another place. The following hypothesis I believe to be applicable in this case:—

If several musical instruments are in tune, and operating in concert, the ear receives their sounds from a distance as if one instrument; but if any instrument gives out discordant sounds, this tends to overcome the more musical sounds and derange the whole. Precisely such are the effects produced by reflected sounds from the solids in an apartment; in the one case, they give consistent strength and effect to each other, but in the other case they produce discord. If in a room certain of the walls are of solid masonry, and others of lath and plaster, and the ceiling is on the principles of a piano-forte sounding board, all having different degrees of action and sound operating in opposition to each other, is it possible that there can be any accordance in the sonorous effects? Causes and effects are in this case similar to that of a complicated piece of mechanism, in which the parts do not fit and move together, but oppose each other; for sound is entirely the offspring of mechanical action in the matter which produces or conducts it.

Mode of Regulating Reflected Sounds intended to reach the ear.—The chief objects in the arrangements alluded to are to obtain reflected sounds of the voice in speech from vertical bodies, so that they may be delivered horizontally on the pinna of the ear, being obviously the direction in which this expanded vibrating lever is best calculated to receive these.

All such reflected sounds must be regulated by the undulatory action in the reflecting solid, each undulation being made to conform in time and duration of sound, as nearly as may be, to the motion of the mechanism of the mouth in the formation of every distinct letter; and these reflections must not be so excessive as to produce any sensible reflection or echo from an opposite solid. To effect these objects, soft non-sonorous material is placed behind, and on the edges of the reflecting sonorous bodies, according to circumstances, so as to moderate the reflections *and shorten the undulations.*

Nature points out that the reflected sounds of the voice should fall on the ear in a horizontal direction, because the voice proceeds from the mouth in this direction whether we sit or stand, and because all cross action in the atmosphere differing from this is found prejudicial.

Means for Preventing Irregular Sounds from reaching the ear, &c.—In order to prevent cross action and derangement in the sonorous atmosphere and in speech, and to keep extraneous sounds from the ear, a greater proportion of soft non-sonorous material must be placed on the unexposed parts of the ceiling and on all sonorous bodies that do not reflect horizontally; but this soft non-elastic material must not be exposed to the atmosphere or the direct action of the voice, except on the floor, because in this case it damps the sound of the voice too much throughout an apartment. By the expansion of air in a room, it ascends, and the sound-producing vibrations naturally ascend with it, acting predominantly on the roof, and not much on the floor, which is, moreover, occupied and covered by the audience to a greater or less extent. Soft material—as matting, or, in places of miscellaneous resort, sawdust—may, therefore, be placed on the floor, without appreciable injury to the voice of the speaker. Some asphaltic compositions—with a preponderance of bitumen, to destroy their sonorous qualities—may be employed with advantage. Extraneous sounds may also be operated on by means of rough or angular surfaces, so as to cause the particles in the atmosphere to act in opposition to each other, in order to break and divide sound, and thus prevent it from reaching the ear. Nature exhibits to us the surface of the ground always in a rough state, so as to prevent any moderate degree of sound, such as emanates from the human voice, from occasioning confusion, because the reflections do not reach the ear.

Lath and plaster are not the most desirable materials for the lining of an apartment; and often in churches, the windows are injudiciously and prejudicially placed, without sufficient means being adopted to keep back from the ear the intense and irregular sound given out by the glass.

THE PROPERTIES OF THE CATENARY.

If a flexible cord, rope, or chain of uniform substance and texture be hung loosely by the extremities between any two points of suspension, it being a matter of indifference whether the points be in a horizontal line, the figure which it naturally assumes and in which it remains at rest, is a peculiar curve denominated the *catenary*, a name derived from the Latin root *catena*, signifying a chain or cord.

This curve, mechanically considered, derives its importance from its intimate connection with the construction of bridges, whether they be built on the ordinary construction of stone or cast-iron, or on the method of suspension by wrought-iron chains.

In reference to the formation of the curve, we remarked that in order to secure its being correctly described, the suspended material ought to be of uniform substance and texture, the object being to have it uniformly pliable and heavy throughout its length. In fact, any want of pliability or readiness to yield to any force applied laterally, essentially alters the nature of the curve; on this account, a chain is likely to afford a more correct curve than a cord. The property of being uniformly heavy throughout is the only positive quality of the material essential to the description of the curve, and it may be stated more particularly by observing that the original force by which the curve is generated is the force of gravity acting equally upon every part of the suspended line; it follows, therefore, that the acting force may be resolved into an infinite series of smaller equal forces acting vertically at indefinitely small distances apart upon the whole length of line suspended.

Let A, B, the extremities of the horizontal line A B, be the

shaft; divide A B into any number of equal parts, A a, a b, . . . and also B C into the same number of equal parts, B 1, 12, . . . draw the horizontal lines a f, b g, . . and draw other lines from the points 1, 2, . . slanting towards A, to meet the horizontal lines respectively at the points f, g, h, . . that is, the line drawn from 1 towards A, to meet the line a f at the point f, the line from 2 towards A, to meet b g at g, and so on; the points b, c, d, e, and f, thus found, will be points in the contour of the shaft, and by joining them into one bent line, A f g h i k C, this line will be the contour, or entasis, as it has been termed, of the column.

But suppose that less swell or bulging is to be given to the shaft; then, in fig. 2, divide A B, as before, into a number of equal parts, and B C into two equal parts at D; divide D C into as many equal parts as A B; then proceed, exactly as in fig. 1, to find the points f, g, h, i, k, in the contour. This will obviously bring the outline nearer to a straight line from A to B. In this figure, E F is supposed to be the axis or centre line of the column; E G and E A being the semi-diameters at the bottom, and F N, F C, the semi-diameters or radii at the top. To explain a third mode of determining the entasis of the shaft: on A G, as a chord, describe the circular arc A O G, proportionally less than a semicircle, as the swell is intended to be less; from the point N draw the vertical line N P, parallel, of course, to E F; divide the arc G P into any number of equal parts, G 1, 12, 23, . .; divide the altitude E F into the same number of equal parts; through the points of division draw the horizontal lines f l, s m, h n, . . . and draw the vertical parallel lines, 1 l, 2 m, 3 n, . . . meeting the others respectively at the points l, m, n, o, p; the curve line drawn through these points will be the entasis of the column.

In many instances the shafts of columns are not finished with plain round surfaces; their surfaces are frequently *fluted*, that is, indented by longitudinal flutes or grooves throughout the whole extent of the shaft. The flutes, when cut are applied entirely round the shaft, and their profile, which is shown by the section of the column, taken horizontally, is generally an arc of a circle, equal to or less than the semi-circumference.

There are two varieties of fluting represented in profile in figs. 3 and 6, Plate I., and shown also in elevation by figs. 4, 5, and 7, 10. In Figs. 6 and 7, it will be observed, that the flutes are regularly separated by fillets; while in figs. 3 and 4, no such intervention exists; the flutes meet each other edge to edge, and form a sharp angle or arris at their junction; the intervention of the fillets, as they strengthen the projecting angles, permits of the flutes being cut much deeper than when they follow each other consecutively. The circumferences of fluted columns are always measured, in the one case, over the exterior surfaces of the fillets, and, in the other, over the angles formed by the flutes.

To describe the flutes of a column without fillets: let A B, fig. 3, be the diameter of the shaft at the lower end; bisect A B at G, and describe the semicircle A E F B; draw A D and B C perpendicular to A B, and D C parallel to A B, touching the circle: draw also D E G and C F G to the centre; divide the semi-circumference into half as many equal parts as there are flutes in the whole circumference; more particularly, let there be twenty flutes in the circumference, then ten of these are due to the semicircle A E F B, and they ought to be so disposed as to have nine of them whole, and the tenth divided between the two extremities A and B, in order that a flute may stand directly in front, as seen in the figure, where the line D C touches the circle. To this end, then, divide the arc E F into five equal parts, and continue the division towards A and B, making two whole divisions and a half, as F d and d c, and c B. These points of division determine the arises of the flutes. To strike the form of the flute, describe arcs from the centres c and d, with the radius c d intersecting at e; from e, with the same radius, describe the concave surface c d; this forms the flute—the same process is applied to find the others. Having drawn the concentric semicircle a b for the diameter of the shaft at the upper end, if radial lines be drawn from the arises of the flutes in the circle A E F B towards the centre G, the points at which they meet the circle a b will be the arises of the fluting at the upper end of the shaft, which is described similarly to that at the bottom. The figure, as now completed, becomes a half plan of the shaft of the column. Fig 4 is a bottom elevation of the column, derived from the plan, as indicated by the dot lines; and fig. 5, is a top elevation.

To describe flutes with fillets in the shaft of a column: Let A B, Fig. 6, Plate I, be the diameter of the column; bisect it at G, and describe a semicircle, as before, upon the diameter A B; draw A D and B C perpendicular, and D C parallel to A B, touching the circle; join D G and C G. Let there be twenty-four flutes in the circumference; there will then be eleven whole and two half flutes in the semi-circumference, and five wholes and two halves in the quarter circumference. If, therefore, this space be divided into six equal parts, the points of division will be the centres from which the flutes are described, and, by running on the divisions to the points A and B, the centres for the whole semi-circumference will be ascertained, and will divide it into twelve equal arcs. Take any one of these arcs, F d, and divide it into five equal parts; then with two of these parts as a radius, from each of the aforesaid centres, describe a semicircle; this will be the section of the flute; the flutes of the interior circle, representing the upper diameter of the shaft, are found by drawing radial lines, which appears sufficiently obvious from the figure. Figs. 7, 8, and 9, are elevations of the bottom of the column, as found from the plan by means of the dot lines; fig. 9, represents the most usual mode of finishing the flutes at the bottom of the shaft; fig. 10, is the correspondin elevation of the upper end.

In describing by relative dimensions the proportions of each particular order of architecture, it is desirable, for the sake of perspicuity and facility of reference, that in all the orders one common standard of measurement should be adopted, to which the proportional dimensions of all the parts of each order should be referred, being expressed in parts of that standard. For this purpose, the diameter of the shaft of the column at the base in each order, is taken as the standard of reference for all the parts or members of the particular order. The advantage of this is twofold, for, first, the proportions of an order are seen by a few glances: and, secondly, the relative proportions of corresponding parts in different orders, are likewise readily ascertained. On this principle, we shall proceed in defining the orders separately. The diameter at the base in each order is divided into 60 equal parts, denominated seconds, and constituting the scale of parts for the particular order; this affords a ready means of accurately noting the proportions, which are expressed in seconds and fractions of seconds when these occur.

ANATOMY AND PHYSIOLOGY.

CHAPTER XXV.

THE ORGAN OF HEARING (CONTINUED).—OF VISION: SECTION I., THE ANATOMY OF THE EYE.

In our last article we alluded to the practice of probing the eustachean tube in cases of obstruction, as well as of forcibly driving air into it with the view of removing the obstructions. Many accidents difficult of explanation have occurred from this practice, showing the necessity of caution in operating upon a part so near the brain.

In the cavity of the ear, called the tympanum, are placed the remarkable chain of small bones already spoken of. The uses of the cavity are not easily understood, and still less have physiologists been able to imagine what the functions of the chain of bones crossing the tympanum may be. Sonorous waves are propagated in the line of their original direction, regardless of all the inflexions of these bones; yet, generally speaking, when this cavity of the tympanum is diseased, hearing suffers. Matter collecting here gives rise to the most intense pain, until it find a vent somewhere.

It is now admitted that sonorous pulsations reach the labyrinth or inner ear in three different ways: 1st, by the chain of bones; 2d, through the osseous walls directly; 3d, across the tympanum, and therefore through the aerial medium found in it. Scarcely anything is known of the mode in which the auditory nerves themselves are affected by sounds. In the labyrinth there is a fluid or semi-fluid, or perhaps both, and probably through it the sonorous pulses reach the fibrils of the nerves. With a magnifying glass of ordinary powers, the nervous fibres of the ear may be well seen in the ear of fishes without any very troublesome dissection; but not of course the primitive fibrils, which require glasses of high power to be observed distinctly. In fishes also may be best observed those singular bodies termed otolithes, of extreme density, and an almost stony hardness in osseous fishes, soft and cretaceous in the cartilaginous kind, and in sharks and skate. These otolithes are represented in men merely by a few very fine crystals, and even these have neither been

well observed nor admitted by all observers. Thus the uses of the various parts of the internal ear or labyrinth is a great mystery. The primitive fibrils of each acoustic nerve has been calculated at 1200; now, every excitement, every concussion of these fibrils, gives rise to the sensation of sound, whether these be sonorous pulsations from without or not. Thus there are *subjective impressions* as well as *objective* sounds; that is, sensations caused altogether independent of an external world. The same, we have seen, holds in respect of the other organs of sense, and in that of sight especially.

In respect to musical sounds, individuals and races of men present the most striking differences. In all the races of men there are persons, and perhaps those very numerous, who have no musical ear whatever. Each race of men seems to have its peculiar music, just as they possess a peculiar form, physiognomy, mental and physical character, and language. No one accustomed to music could well mistake the music of the Russ or Sarmatian race for that of the Saxon or Celtic. What is called German music evidently partakes of two distinct characters, marking the distinct origins of the present races chiefly occupying Germany, viz., the Teutonian or Scandinavian, and the Goth, Hun, or Southern German. The pure Saxon race has no ear for music; hence England has not only no national music, but not even a national air. It would be extremely difficult to guess at the origin of the Italian music; and in respect to its being hard to the Greek, it may be remarked, that the modern Greek—at least it is asserted—has no musical ear. The extraordinary effects of *association* may best be understood by observing the enthusiasm with which the frightfully noisy and vulgar sea songs, and some others called national, as "Rule Britannia," "God Save the Queen," "British Grenadiers," &c., are received by audiences, who, being destitute of all musical ear, still imagine these wretched Scandinavian and Norwegian tunes to be melodious and musical. It has been said by some one, that Dibdin received a pension from George III. for destroying the public taste; but this was a mistake in one sense, seeing that no public taste existed. The Dutch are, in this respect, much as the English; they have not been able to compose a single air since they have existed as a people on the face of the earth. Nor will even the Celtic race, wherever found, have the musical ear and a national music; witness Ireland, Wales, and the Scottish Highlands.

Does double hearing ever occur like double vision? Some cases have been recorded, but they are exceedingly rare. We have no direct mode of judging of the *direction* or distance of sounds. Lastly, it would seem from the investigations of the ingenious Wollaston, that there are "sounds inaudible to certain ears;" the chirp of the grasshopper, for example, and the cry of the bat.

OF VISION.

SECTION I.—THE ANATOMY OF THE EYE.

It is universally admitted that the eye is an optical instrument of singular perfection; to understand, in so far as they can be understood, the functions of its several parts, requires a knowledge of the science of optics, together with an acquaintance with the structure of the eye itself. The human eye and its functions will chiefly engage our attention in the following brief remarks.

By means of this organ we not only are aware of the presence of light, but through it as a medium we take cognizance of the size, colour, position, and form of surrounding bodies.

With regard to the nature of light, two opinions are held by opticians. The one is, that its rays are composed of actual particles which radiate from luminous bodies; the other supposes the existence of a very subtle fluid, or ether, which extends over all space, and that the light consists in undulations or vibrations of it. The latter is probably the true theory; but the discussion of the merits of the two is uninteresting to the physiologist, inasmuch as the laws concerning the transmission of light are the same under both systems, and, moreover, are fortunately well understood. Some of these it is necessary to allude to.

When light passes through any single transparent body, as air or water, it always passes in straight lines; but when it passes from one transparent body to another, as from air to water for instance (except, indeed, when it falls perpendicularly upon the surfaces where they join), it undergoes a change of direction, or, to use the technical expression, is refracted. A familiar instance of this is seen by putting a cedar pencil into a tumbler of water, when, owing to this law, the part of the pencil under water will seem to form an angle with the part remaining above.

The degree of refraction varies in different bodies. We judge of it by supposing a perpendicular to be drawn to the surface of junction of the two transparent bodies, at the point where the ray of light quits the one and enters the other; and we observe whether its change of direction, in its course through the second body, be towards or from that perpendicular. If it be refracted towards the perpendicular, we say that the substance which it enters has the greater refractive power of the two. We find that, generally speaking, dense bodies have a greater refractive power than those which are rarer, as water or glass, for instance, than air.

When the surface which separates the two media is not flat, but either convex or concave, the direction of the rays of light which fall upon it is altered. Thus, in Plate II., fig. 2, *b b* is a convex piece of glass, and *a* is a luminous body, from which three rays are issuing. The central one, *a c*, falls upon the glass in a perpendicular direction to its surface at that point, and therefore passes on unchanged. But the ray, *a d*, on entering the surface, will be bent towards *e*, which is perpendicular to the surface of the lens at the point where *a d* enters; therefore, as glass has a greater refractive power than air, *a b* will pass on in the direction, *f*: in like manner, *a g* will be directed towards *i*. It is evident that, if these rays were prolonged, they would meet each other. The point of meeting is termed the focus.

On the other hand, the reverse would take place if the rays passed from a denser medium into one more rare. It is thus evident, that when a ray of light, passing through air, falls on a convex lens of glass (*i. e.* a piece of glass bounded upon each side by a segment of a sphere), or any other transparent medium denser than air, it will undergo two refractions—one when it enters the lens, and the other when it passes out; and it is farther obvious, that each refraction will bring it nearer to the axis of the lens.

If different rays, proceeding from the same object, pass through air, and fall upon a convex lens, the result of these two refractions will be to concentrate all these rays into a focus beyond the lens.

As a convex lens concentrates all the rays from a distant *point* into a focus, so it concentrates all the rays from a distant *object* into an *image*.

Now, the eye is essentially a convex lens, by means of which the rays of light, proceeding from an object, are concentrated behind it into an image, which, being placed upon the termination of the optic nerve, produces in the brain the sensation of sight. Nothing, perhaps, in nature presents so many beautiful contrivances for effecting this purpose as the eye does; and vision has always been considered to afford some of the best illustrations of Natural Theology.

The eye, or eyeball, situated deep in the orbit, is protected in front by the eyebrows and eyelids, and its surface is kept constantly moist by means of the secretion of the lachrymal gland, placed upon the outer side of the eye. The secretion from this is always oozing, and, passing over the eye, is carried into the nose through the little canal, the orifice of which is seen in the inner corner of the orbit. Mental emotion causes great increase of this secretion.

The eyeball is nearly spherical. It consists of membranes placed one within the other, and humours, or fluids, which these membranes contain. It is connected with the eyebrows by means of the conjunctiva, a mucous membrane, which, lining them, is reflected over the anterior part of the eyeball. The fig. 1, Plate II., represents a section of the globe of the

eye, &c. The sclerotic coat, or membrane, No. 1, is a firm fibrous membrane, and forms about four-fifths of the external investment of the eye. Posteriorly, it is penetrated by the optic nerve, 17. In front it is joined by the transparent cornea, 3, which is received within it after the fashion of a watch-glass: this is seen at 2. Just at the point of junction is a ring of light-grey matter, 4, called the ciliary ligament. The choroid membrane, 5, lies underneath the sclerotic, and is essentially a vascular structure, and terminates anteriorly in sixty or eighty little processes, called ciliary, 6. Underneath the choroid membrane is seen the retina, 7, which is nothing but the expanded termination of the optic nerve. Upon looking through the cornea, we behold a coloured circle: this is the iris, 8. This structure is muscular, and is perforated in the centre by an aperture well known by the name of pupil. By the contraction of the fibres of the iris, the size of the pupil can be changed, and is so changed according to the intensity of the light—being larger when there is little, and smaller when there is much glare. Of course, this is done independently of our will. The iris is suspended in a cavity, bounded in front by the cornea, and behind by the crystalline lens, 13. This is occupied by the aqueous humour. The space between the iris and the cornea is termed the anterior, 9, and that between the iris and the lens, the posterior chamber, 10. To speak exactly, the aqueous humour is in the anterior chamber, surrounded by a very thin membrane, 12, which secretes it. The lens is doubly convex, and perfectly transparent. Behind it is the vitreous humour, 15, which fills up the posterior two-thirds of the eye. It is surrounded by a thin membrane, which also forms a number of processes, projecting inwards, and dividing it into detached masses, 16, 16. Both the humours of the eye are almost entirely composed of water, containing only about 2 per cent. of animal and saline matter, while the lens contains 42 per cent.

The muscles of the eyeball are six in number, and, with one exception, originate at the back of the orbit, and are inserted into the sclerotic coat. These perform all the motions of the eye; and it is when one or more of them is contracted, that we have that form of squinting which can be relieved by an operation. The different motor nerves, arising from the brain and entering the eyeball, supply these muscles.

When the eye is turned towards any luminous body, whether it evolves light itself, as the sun, or reflects light, as almost all visible bodies do, the following phenomena take place. The ray of light which falls perpendicularly upon the centre of the cornea undergoes no refraction, but passes on through the transparent humours and lens to the retina. All other rays coming from the same object are refracted—first, when they enter the cornea and aqueous humour; then when they enter the lens, which has the greatest density and refractive power; and, lastly, when they pass from the lens to the vitreous humour. All these refractions are toward the axis of the eye, and hence all the rays meet about the same point of the retina where the ray which fell perpendicularly upon the cornea did. As before stated, as the rays from a point form a focus, so do those from an object, or set of objects, form an image or picture upon the retina, which gives us the sensation we call sight.

A little consideration will show that this image upon the retina must be inverted, or upside down. Plate II., fig. 3, represents two rays* issuing, one from each extremity of an arrow. These rays cross each other in the middle of the eye; those from *a* are brought to a focus at *b*, and those from c to one at *d*. In fact, if we examine the eye of an animal recently killed (for the coats and humours of the eye soon lose their transparency after death), the image can be seen upon the retina in the position we describe it. It is not easy to explain how it happens that we see the objects erect. It is not that the infant at first really sees everything the wrong way up, and learns his error by inference; inasmuch as in people, who, having been born blind, have obtained their vision at a mature age from an operation, no such thing has been felt, but they at once see objects erect. Some peculiar nervous arrangement, into which it is impossible to enter here, is probably the true explanation of this circumstance.

As the dissection of the fresh human eye is obtained with difficulty, and might even be unpleasant to many who may peruse this article, the writer recommends that in its stead the reader place before him the fresh eye of the sheep, removed from the head soon after death, and with a small knife, scissors, and forceps, he may, without the aid of any instruction, acquire such a knowledge of all the structures as will suffice for his understanding the functions of every individual part about to be spoken of. Let him commence with the back part of the mass coarsely removed from the orbit, and he will first observe the *optic nerve*, which has been cut across at the point where it passes from the orbit into the interior of the cranium, on its way to the brain, in which it terminates. If the dissector follows this nerve towards its other termination, viz., in the eye-ball, removing or cleaning and pushing aside the structures he meets with, he may probably observe, and ought to examine, the muscles connected with the eye-ball; all these muscles were connected with the osseous orbit before the eye was removed from the orbit; they are the four recti and the two obliqui muscles; which all commence or are attached at the bottom of the orbit, or around the entrance of the optic nerve into that cavity, with the exception of one, the obliquus inferior muscle. Tracing each of these muscles forward, he will find that they terminate by a thin tendinous expansion inserted or attached to the eye-ball. The uses of these muscles may be here stated generally to be, to move the eye-ball in every direction; to roll it about with the utmost facility, and to direct the axis of the eye-ball towards any object we propose attentively examining. In this way the axis of each eye is directed towards the same object, and the parallelism of both eyes maintained. All these muscles are supplied with nerves, viz., the 3d, 4th, and 6th, and some filaments from the 5th pairs, and no doubt also from the sympathetic system of nerves; the reason why so many distinct pairs of nerves proceed to the muscles of the orbit has never been explained, neither do we as yet rightly understand the functions or uses of these individual nerves and muscles.

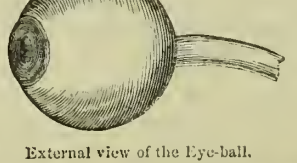
Let the reader proceed with his dissection, and cutting away or laying aside these six muscles, together with the elevator muscle of the upper eye-lid, which he may also have observed at the commencement of the dissection, and lying more superficial than the straight muscles, he will find a cushion of fat, with nerves passing through it in many directions. This cushion of fat has also its presumed uses; the eye-ball, as it were, rests upon it, or is pressed against it by the muscles already spoken of: and it is said that when from disease or want of a sufficiency of food, this cushion has been absorbed into the general system, producing a remarkable hollowness in the eyes, the animal will certainly die. However this may be, there is no doubt a state of extreme emaciation from which no animal can recover.

Having cleared away this cushion of fat, the reader will next observe a set of strong muscular fibres closely embracing the optic nerve, and attached all round and very firmly to the eye-ball. This layer of muscles is peculiar to the lower animals, not being present in man; he need not therefore regard it, but cut it freely away, and clear at once all the outer surface of the eye-ball, observing carefully the point where the optic nerve enters the globe of the eye. The part he ought next to examine is the strong nerve forming the exterior of all the back part and sides of the globe of the eye: a white fibrous tunic of very considerable strength. Into the fore part of this tunic, which is called the sclerotic, is inserted a circular and perfectly transparent convex plate, (the cornea), like a window. Through this transparent lamina the rays of light penetrate into the interior of the eye-ball; a fine membrane, also transparent, connects this plate or cornea and the eye-ball generally, to the eye-lids.

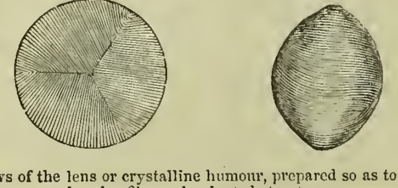
* We only give two to render the diagram clearer; but, of course, rays would proceed from all parts of the object.

By cutting into the tunica selcrotica, or outer fibrous protecting covering of the eye, the reader will perceive immediately subjacent a dark membrane covered outside and inside with a pigment. This membrane is the choroid; it is extremely vascular, and through it at the back part, as likewise through the sclerotica, the optic nerve passes into the interior of the eye. Let the dissector now remove a portion of the choroid with his scissars and forceps, and underneath he will find that layer of nervous matter called the *retina*, in immediate connection with the optic nerve, thought by some to be an expansion of it, and constituting the most important part of the organ of vision, for whose protection indeed all the other parts are formed. Before considering the uses of all these parts, let the reader proceed with his dissection, for without having first seen its structures, it is quite impossible for him rightly to comprehend any discussion on the uses of these structures.

If he now scrapes off a small portion of the layer called the retina, he will find that it is supported by a rounded very considerable mass, of a perfectly transparent substance like jelly or melted glass; hence called the vitreous humor, and more recently by De Blainville, the *vitrine* of the eye. This substance is enclosed in a membrane also perfectly transparent. Thus, passing through successive layers of membranes placed over each other, like the layers of an onion, the dissector arrives at the transparent humors filling up the interior of the eye-ball, and composing by far the greater part of it. These humors are three in number, viz., the aqueous, the chrystalline, and the vitreous. The best way to examine them is to make an opening into the transparent lamina called the cornea, whence the aqueous humor will immediately escape; its quantity and appearance may thus be estimated and understood—next cut away the whole of the cornea, and thus expose the moveable circular curtain called the iris; in the centre of the iris will be found an opening which is circular in man, but not quite so in the eye of the sheep. This opening is called the pupil of the eye, and is spoken of in common language as if it were a real existing body, whereas it is merely an opening in the iris. By passing a probe through the opening the dissector touches the capsule of the lens or chrystalline humor; now, to get a satisfactory view of the lens and vitreous humor, let him cut away all the tunics when these humors will be left on the table, connected together by their tunics, and freed from all other connections.



External view of the Eye-ball.



Two views of the lens or crystalline humour, prepared so as to show its singular fibrous laminated structure.

It were easy to have multiplied figures of the structures of the eye, but with no probability of enabling the reader to understand structures he has not looked at and handled. With a single remark, then, I shall close this section, intending in the next to examine more minutely, that is, in fact, physiologically, into the uses of all the structures here spoken of.

Whilst dissecting the eye of the sheep, ox, horse, or dog, or indeed of most quadrupeds, the dissector will observe, besides many other specialities peculiar to each species of animals, that a portion of the choroid towards the bottom of the eye, or its inner surface, has a bright metallic lustre; this appearance is called the Tapetum, and it is this which gives to the eyes of these animals the power of glaring in the dark, or when the most obscure light is present. Man has no such structure, and therefore his eyes never glare.

The lachrymal apparatus of the eye is shown in Plate II., fig. 5. We shall explain, in next section, the physiology of this organ, and some of the peculiar diseases to which it is liable.

DESCRIPTION OF A PORTABLE DIORAMA.

BY GEORGE TAIT, ESQ., ADVOCATE.

The diorama, the ingenious invention of the celebrated French artist Daguerre, is a painting, fitted up so as to receive light both in front and behind; by the full or partial admission, or the total exclusion, of either of which lights a great variety of effects may be produced. No light is admitted to the eye except that which proceeds from the painting.

The diorama is usually executed on an extensive surface of canvas, and placed in a large building fitted up for the purpose.

It occurred to Mr. Tait that it might be made upon a much smaller scale; and, accordingly, (before the publication of Daguerre's description,) that gentleman constructed, for the reception of sketches in water-colours which he painted for the purpose, a small box, having, for the admission of light before and behind, openings capable of being closed by moveable shades, and having also a small opening in front, through which the sketches might be viewed. Upon trying a variety of sketches in this apparatus, he found that many pleasing and striking effects might be produced: for example, passing gleams of sunshine; day melting into moonlight; day fading into darkness, followed by morning gradually disclosing the landscape, having its former verdure shrouded in snow. For this ingenious and elegant contrivance, Mr. Tait was honoured with the medal of the Scottish Society of Arts.

In Vol. I. p. 613, an account was given of a modification of the apparatus, by which the pictures, being placed in front of the box, were exposed uncovered, so as to be viewed by a number of persons at a time. This was a decided improvement on the first arrangement; but still there are certain advantages in point of striking effect attending the original form, which render it worthy of being described in detail, while taking occasion to present to the reader some of the inventor's observations on the management of the apparatus, the preparation of the pictures, and proper light to be used.

I.—THE BOX.

Stretching frames are to be prepared for receiving the paper or linen on which the pictures are to be executed; and as these are confined within the inner edges of them, the frames ought to be made thick and narrow, so as not unnecessarily to increase the width of the box, and should be bevilled off to allow access to the brush in painting the back. Those frames are inserted in succession through a slit in the top of the box, about two-thirds distant from the front, and are received into a groove projecting from the top, sides, and bottom of the box, of such a breadth as fully to cover the front of them.

Two openings, one above in front and the other behind, admit the light; and both should be as large as possible. The front opening ought to be of the form seen in the figure, in order to admit the light gradually; an erect right-angled triangle, with its base across the breadth of the box, being placed immediately behind the front opening to aid this object. The openings have a ply of fine tissue-paper, Persian silk, or other appropriate material, placed over them, to diffuse the light. This is moveable and is usually white, but may be of an orange, purple, blue, or other tint for particular purposes; and one or two plies may be used according to circumstances. The shades for the openings may be made to open and close in any manner found convenient, but so as to exclude all light when closed.

The small opening in the front, through which the pictures

ANATOMY & PHYSIOLOGY.

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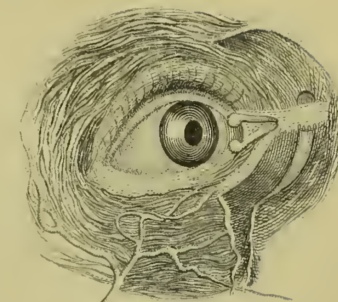
Fig 4

NEBULA

Fig. 6.

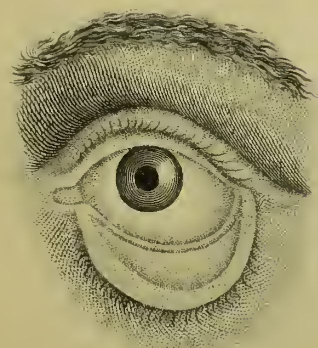
PTERYGIUM

Fig 5.



LACHRYMAL PARTS OF EYE

Fig. 7



ECTROPIUM

Fig 8

CURED ECTROPIUM

Fig

Fig 1

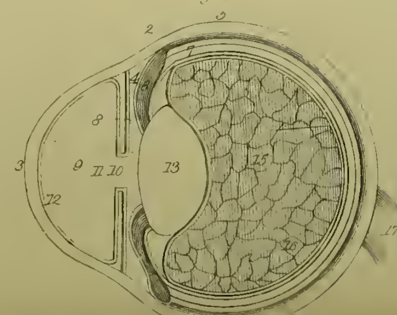


Fig. 3

ANATOMY AND PHYSIOLOGY.

CHAPTER XXVI.

OF VISION (CONTINUED).—SECTION III.: PHYSIOLOGY AND DISEASES OF THE EYE.

The adaptation of the eye to the perception of the external world, by means of colours, is a fact which has been much enlarged upon by many philosophic and popular writers, and consequently need not be here dwelt on. The human eye may be said to be an extremely perfect organ, without claiming for it any exaggerated powers. There are animals superior, no doubt, to men in their powers of vision, as the eagle, and especially the vulture; whilst even amongst men it is not in the most gifted races that we find the strongest range of vision. In this respect, the eye of the negro, but more especially of the Hottentot and Bosjesmen of Southern Africa, far excel the European and, probably, all other races of men.

The essence of the organ of vision, wherever found, consists in "a series of transparent media being placed in front of a special apparatus;" that is, of an expansion of a portion of the nervous system having interposed between it and the external world a series of transparent media, each possessing powers of refraction, and otherwise modifying the rays of light proceeding from luminous bodies through these media, until they impinge or affect the retina, that is, the sensitive organ, for the sake of which all the other parts were formed. Even in the leech and in the sea-worm there is a pupil admitting the rays of light into the interior of the eye. Something analogous to the lens and vitrine follow this, or are placed behind it, refracting the rays of light to the requisite extent, and no doubt causing them to meet in a focus upon the nervous points, or fibrillæ, which are placed in the back of the organ. The evil effects which flow from an opacity of the cornea or of the lens in man, unhappily illustrate too well the necessity for the transparency of the media between the retina and the external world; deep opacities of the cornea render the organ useless by impeding or arresting the progress of the rays of light in their course towards the retina. Some ingenious attempts have lately been made to remove the opaque cornea, and replace it by a healthy transparent one taken from the eye of another animal, but it is extremely unlikely that such experiments will ever succeed on the human eye.

The surface of the eye-ball in the young and healthy has a peculiar lustre, which it loses so soon as the frame suffers from debility, exhaustion, or distress of mind. The lustre may either be simply healthy and natural, or morbidly exalted, as in passion and during the accession of intense fever; and in mania and delirium, however induced. The immediate cause of the lustre of the healthy eye is probably the action of the muscles of the eye-ball maintaining it firmly in its place, pressing it against the fatty cushion against which it rests, and giving to it, in short, that tension necessary to render the cornea prominent, clear, and full. In general, as life ceases the lustre departs, although there are exceptions to this, which it would not be difficult to explain. As life ceases all the muscles of the body lose a part at least of their general tone, and so also do those within the orbit. A curious fact having reference to this was first noticed by the late Dr. John Barclay. As he was preparing by dissection some sheep's eyes for demonstration to his class, he accidentally squeezed one of them firmly in his hand; as the pressure continued, the cornea became at first bluish, and afterwards more and more opaque, until it seemed to have lost altogether its admirable quality of perfect transparency. On relaxing the pressure, the cornea recovered its transparency. The cause of this has never been explained; but as it is a fact, that the cornea loses something of its transparency by strong pressure exercised on the eye-ball, the circumstance may perhaps explain the confused and indistinct vision of persons labouring under the delirium of passion, in whom the muscles of the whole frame become violently agitated, a condition extending no doubt to those within the orbit. But indistinctness of vision does no doubt arise in those who are passionate or mentally disturbed from another cause, which we shall shortly explain.

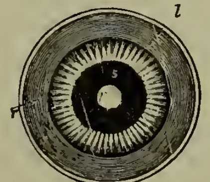
The human eyes then, like those of all other animals, possess in health an admirable lustre, though they never glare like those of the lower animals. All that the poets have written about this is, as usual, mere nonsense and contrary to truth, to which they in general pay no respect. But there are phenomena to which they have attended, which, being more in accordance with physiological laws, may here be noticed.

A person intoxicated, or in a phrenzy of passion, or agitated with fear and in deep terror, sees objects double; that is, he has lost for the time the power of directing aright the axes of both eyes towards one object; hence there may be more literal truth in the remark than at first appears,

"Fear doubled his enemies."

Adverting now to the uses of the various parts of the eye, we may mention first the aqueous humour. It is to it that the cornea owes its fullness, and when this is punctured the humour escapes very readily. It is as readily restored, however, by the ordinary powers of the animal economy. Of the iris we have already spoken. In the eyes of the Saxon race it is of a blue or grey colour; in the negro, quite dark, thus partaking of the general system of coloration of the whole body. Letters have been fantastically read on it by heated imaginators. Its most remarkable, and as yet inexplicable faculty, is that of so narrowing and expanding as to alter the dimensions of the circular aperture found in its centre (the pupil), thus admitting more or less fully into the interior of the eye the rays of light. This admirable and wonderful faculty in the iris was known to Aristotle. It could not indeed have escaped the notice of any observing person. Moreover, if a person be desired to look at a very near object, and the movements of the iris be watched, it will be seen to contract almost to a point until, the effort becoming painful, it suddenly relaxes, and the pupil is restored to its former average dimensions. If he be then desired to look at a distant object, the pupil may be seen to dilate. These movements do not imply, however, that we have any real voluntary control over the motions of the iris, although the parrot is said to possess this; and the same may be said, I think, of the cat, lion, and tiger. To explain these movements, physiologists have been forced to presume the existence of certain structures in the iris which have not been fully proved; namely, radiating muscular fibres, and a sphincter muscle; as thus:

Fig. 5.



A view of the interior surface of the iris.

b, The base by which it is fixed to the choroid tunic and annulus albus; *p*, the pupil; *r*, the radiating fibres; *s*, the sphincter.

Upon the whole, however, physiologists are agreed that it serves at least the same purpose as the diaphragm placed in the optical instruments to correct or prevent the indistinctness of vision arising from the spherical aberration of the lenses.

The iris abounds with blood-vessels, and especially with nerves, and more especially in animals of quick and rapid vision, as in birds, antelopes, deer, &c.; in man also the iris is well supplied with nerves. These movements of the iris would seem, in a certain degree, to be connected with a singularly beautiful power the eye possesses of adapt-

ing itself, with more or less rapidity, to the distinct perception of objects more or less remote. We shall consider this faculty when speaking of the annulus albus, or ciliary ligament.

Of the refracting media placed within the eye-ball, the lens is admitted to be the most important; it serves, in fact, the purpose of a magnifying glass or lens of very great powers placed within the eye. It presents within the eyes of various animals a great variety of forms, being perfectly globular in some, as in fishes; and in man and in birds, biconvex. This form seems best adapted for an extended range of vision. The lens of the cod and haddock when quite fresh may be used as a magnifying glass; and it may probably be owing to this globular form of the lens in fishes, that some of them at least see animals in the waters which are perfectly microscopic to man. This is the case with the verduce of Loch Maben, which lives exclusively on microscopic entomostracea, or shell fish, so small as to be invisible to the unaided human eye. The herring lives chiefly on the same food; the char also, and at certain seasons of the year, one kind at least of the Lochleven trout. Other aquatic animals, besides fishes, have the lens of a globular form; and this property extends also to the more common quadrupeds, and is not peculiar to them.

The lens is said to be without structure, and without blood-vessels or nerves; in this respect, therefore, it is an excretion, and has been compared to the hair, nails, and teeth. It is certainly quite free in its capsule, which contains besides a small quantity of liquid termed the liquor of Morgagni. In this liquid of Morgagni recent observers have noticed some singular spindle-shaped bodies. The surface of the lens is soft and cellular, but underneath this it is fibrous and laminated like an onion, and is moreover said to possess an arrangement of matter which no art has yet been able to approach; namely, a progressively increasing refringent power by a density progressively increasing from the circumference to the centre; such an arrangement no doubt contributes to correct in the human eye that phenomenon called irization, found to exist in certain telescopes.

It has occurred to me to observe many peculiarities in vision, which, though noticed merely in individuals, may yet characterize numerous classes. I have known persons of the very finest and most acute sight who could not employ or use a common botanical lens or magnifying glass; their sight did not seem to require it. Moreover, it is a great mistake to suppose that what one person sees readily should be as readily seen by others possessing sound vision. The eye must be exercised, and many who have not previously seen the object can with great difficulty be instructed how to look for it. A few years ago Sir John Herschell discovered with the aid of a microscope of high powers an arrangement of matter hitherto unobserved; he published the fact, but although carefully looked for, some of the first observers in the kingdom failed in rediscovering it. At a meeting with Sir John Herschell, Sir D. Brewster mentioned the circumstance, when, with a slight modification not attended to by them, the structure in question was made manifest to all.

A remarkable proof of the difficulty of pointing out even to the acutest sighted of men an object which they have *never seen before*, or which, from its *magnitude*, or *form*, or *colour*, or diminutive size, is altogether different from their preconceived notions, occurred to the author whilst residing on the frontiers of the colony of the Cape. After the expulsion of the Amokoss Caffre race from the territory watered by the Koonap, Kat, and Keiskenne rivers, by the British in 1820, it was deemed advisable by the colonial government to declare the territory for the future a "Neutral Territory," which was not to be occupied nor encroached on permanently by either race, British or Caffre. Into this tract of country the "wilde," or game and wild beasts as we term them, rapidly returned: the absence of man, the agreed enemy and chief destroyer, offering them every security. Into this territory as a precautionary measure, "patroles" of small parties of armed men were sent by the British; small detachments, in fact, from the regiments stationed on the frontiers. One of these, consisting of fourteen men and commanded by Ensign C., I accompanied, my principal object being to ascertain the precise junction of the Koonap and Kat rivers, a spot which, so far as I could learn, had never been visited by any European. Now, it happened that neither Ensign C. nor any of his party had seen an elephant, a circumstance which was incomprehensible to me, seeing that they had frequently patrolled over a district which I knew to abound not only with elephants, but with every sort of "*wilde*." Accordingly I promised him that before the close of the third day (the limit of our patrol) I would most certainly be able to point out to him a drove or two of those wondrous animals, for I knew that they visited that district in droves of three or four hundred at a time. Our first day's route lay along the high lands connected with the course of the Koonap river, which the elephants had for the time seemingly abandoned, as none were met with; but on the forenoon of the second day, having crossed the Koonap, and as we marched towards the point I was desirous of examining, namely, the junction of the Kat and Koonap rivers, I discovered at the distance of about a couple of miles a drove of elephants of at least three hundred in number. A grassy plain, on which grew a few scattered mimosas, lay between the parts and the wooded hill, on the northern slope of which, scattered over its whole surface, grazed the majestic animals we were in search of. The hill was a portion of a range of hills dividing the territory we were now in from the wild, desolate, and unprofitable district of the Great Fish river; it was, like the others, not covered with forest trees, (for there are, properly speaking, no forest trees here,) but with tall bushes, some of them fifteen or twenty feet high, and only partially covering the sides of the hill, the brown clay soil appearing at intervals. I mention these circumstances as they tend to explain the singular occurrence which next took place. The instant I saw the side of the hill it was easy for me, the appearance being quite familiar, to distinguish hundreds of elephants quietly browsing on the tall bushes covering its surface, and I pointed them out to Ensign C. and his party; but although they gazed at the hill and at the elephants which I distinguished so clearly, none of the party could discern a single animal. It was in vain that I pointed out to them the enormous living masses moving among the bushes, which at times their carcases obscured, and by which they were at times lost to view; the movements of the proboscis, the gambols of the young, were all distinctly visible to the experienced eye—to the military party they were perfectly invisible. Baffled in my efforts to enable the party to discover the drove, Ensign C. and myself (the only persons of the escort who were on horseback) rode gently forward towards the base of the hill, across the open grassy plain, when, coming within about a mile, the whole drove became at once visible to him, and he stood astonished; first at the sight, and afterwards at the difficulty he had experienced in discovering objects of such magnitude; whenever indeed the precise outline of one elephant was clearly made out, all the rest became apparent; the difficulty seemed to be, *the clearly perceiving one*. As far as I can recollect, none of the party we left on the verge of the plain made them out.

Another observation, something similar in character, is a seeming narrowness of mental and bodily vision, disabling the person from grasping at one view all the details of an object presented to him. The result is, that the whole is unintelligible, by reason that he sees it only in detail. Many remarkable instances of this deficiency once occurred during the exhibition of the great northern whale in the exhibition rooms of the Royal Institution in Edinburgh—numerous highly educated persons were found altogether unequal to the making out of the form of the skeleton, as exhibited, although to others of a wide verge of mental and bodily vision nothing was more distinct. It would be difficult to say how this arises; with some it might be owing to their preconceived notions of the relative bulk of individual parts having had so strong hold of their minds as to disqualify them from conceiving or of perceiving in nature forms so different from those with which they were familiar.

Another peculiarity in the vision of different persons is the power of rapidly adapting the eye to various distances. This is essential to the sportsman, to the observer, to the engineer

in short, to all men who pretend to be observers. The seat or cause of this faculty, which the eye possesses, has never yet been well explained: some ascribing it mainly to the iris: others to the external muscles surrounding the eye-ball: and others to a peculiar ring or circle called the *annulus albus*, whose position is near the junction of the cornea and the sclerotic tunic. On whatever this function of the eye depends, certain it is that all men possess it, but in very limited degrees; mere children, for example, have it in a very inferior degree, whilst in some military men, with the very best vision, it is so slowly increased as to be of no use to them in the field. I well remember an officer whose sight was remarkably powerful, and who could, once the object was fairly seen by him, make out all its details at incredible distances; but the difficulty always was, to get him "*to see the object*": once seen, he saw it better than any of us. On this principle I feel disposed to explain how it is that many persons will travel over strange lands and *see nothing*; I rode once, with another officer, through a lovely valley full of game; in half an hour I counted at least 40 head of game, from the rhinoceros to the partridge; my friend returned exactly as he went—he had *seen nothing*. Caille, who says he travelled from the mouth of the Gambia to Timbuctoo, and never saw a wild animal, must have resembled my friend in this respect.

The Retina (see Plate) or the expansion of the optic nerve, as some are pleased to consider it, is the most difficult to examine of all the structures, and the least understood. The Germans point out arrangements in its ultimate form, which have not been confirmed in this country. The membrane, which is a complex, and not a simple one, is still presumed to be the immediate instrument of vision, and to form the harder surface upon which is depicted the image of all external bodies seen by us. These views are quite hypothetical, and are rendered even improbable by the fact that, in the *axis of vision*, where alone we perceive and see distinctly, the *pulpy or nervous retina* is wanting; there is, in fact, a hole in the membrane at the point where we see best; *where* the optic nerve enters is the *punctum non videns*, or point at which we do not see. The range of distinct perception is extremely limited; of this truth any one may satisfy himself by endeavouring to count the books on a shelf, when he will find that he cannot count more than one properly or two at most without continually shifting the axis of vision.

The choroid tunic is the vascular and varnishing membrane of the eye; it converts the eye into a camera obscura. The sclerotic is the protecting fibrous membrane; the uses of the other parts of the eye have been already referred to. Both eyes are required to decide with due precision on the distance of any very near object, although it seldom happens that both eyes have equal power; nay, in numbers of persons one eye is found to be altogether or nearly useless, although this could not be surmised from any external appearance.

The theory and history of the subjective phenomena of the organs of vision, viz., apparitions, phantoms and spectres, has been so fully and so ably treated of by Dr. Hibbert, Sir D. Brewster, and others, that any remarks here might appear out of place, or at least superfluous. With a few further remarks then we shall close this section.

1st, There is a harmony in colours, exemplified by what we see in the dresses of various nations placed under different circumstances, as to light and shade; nothing, for example, looks worse in our cold, cheerless, cloudy country, with its china ink skies, than the gaudy dress of the oriental races, their white and yellow robes, their bright colours, their gaudy tinsel ornaments. On the other hand, an Englishman with his duffle and drab or black coat, and brown waistcoat, is the most ludicrous looking animal in the world under the Persian or the African sun.

2d, Wagner, one of the latest writers on Physiology, thinks that even yet no true theory has been offered of the curious fact that, whilst all the objects of the material world are painted, or represented on the retina of the eye in an inverted position, we still see them correctly, and not inverted but upright. Many years ago an explanation of this singular fact was offered by Mr. Alexander, Walker a most distinguished anatomist and physiologist; his explanation rested on the fact, that the fibres proceeding from the retina to the brain are inverted in their course, that is, those proceeding from the lower parts of the retina reach the upper part of the brain, and *vice versa*; this, of course, produces an inversion of the ideas.

DISEASES OF THE EYE.

The eye, as may be supposed from the complexity of its structure and uses, is liable to many diseases.

Sometimes the optic nerve, or retina, is palsied, and the disease called amaurosis, or, more familiarly, gutta serena, is produced. At other times the transparency of some of the refracting media is destroyed, and the rays of light thereby prevented from impinging upon the retina. Such constitute the affections of cataract and glaucoma.

Both the lens and its capsule are liable to opacity, which more or less impedes vision, and constitutes the disease called cataract. The lens, when thus affected, is sometimes softer, and at others harder, than natural, and hence the systematic writers describe a hard, soft, and milky cataract.

The causes of cataract are very obscure. One of the predisposing causes of it is old age, and the tendency to it seems to be hereditary. The exciting cause is sometimes a blow upon the eye, but is as often not appreciable.

Cataract may be known by two positive and one negative symptom. First, the pupil, instead of being black, is brown, yellow, or white. Secondly, the vision is defective, and there is sometimes complete blindness, except that the power remains of discerning the outlines of objects held between the eye and the light. Thirdly, the iris is moveable.

In general, cataract comes on gradually, the opacity, and, consequently, dimness increasing by slow degrees. During this progress, the patient always sees best in an obscure light, because in such the pupil dilates most, and exposes the lens towards the circumference, where the opacity is always least.

The only cure for cataract is a surgical operation, and three methods of thus treating it are in use. One of these is called couching, and consists in putting a needle into the eye, and pushing down the opaque lens. Another consists in cutting out the lens altogether; and the third consists in introducing a needle, and breaking up the lens into bits, which are subsequently absorbed.

The best mode of treatment is held to be, in general, to introduce a curved needle through the sclerotic, and depress the lens, if found to be firm, and to break it up, if soft.

After the operation, the patient requires to be confined for some days to a darkened room, and observe an antiphlogistic regimen.

With reference to glaucoma, a similar affection, Cooper observes, that in this disease the eye is green or yellowish-green, and if the eye be looked at laterally, no discoloration is seen. In cataract, the pupil is grey or greyish-white, and it has the same appearance in whatever direction it is viewed. In glaucoma, the loss of vision is not in direct proportion to the change of colour in the pupil. With an inconsiderable change, vision may be entirely destroyed, or seriously impared; but in cataract, there is a direct proportion between the degree of opacity, and the injury to sight. In cataract, vision is best in a weak light; in glaucoma, it is stronger in a powerful light, because, as the retina is less sensible, more light is required to make an impression on it."

Almost all the tunics and other parts of the eye are liable to inflammation; the conjunctiva is more particularly so; and in this the inflammation may be set up by exposure to bright light, intense heat, cold winds, dust, and foreign bodies, and also by disorders of the stomach. Moreover, when the conjunctiva has been once inflamed, the inflammation is very apt, from slight causes, to recur. This inflammation is sometimes very acute, and at others quite chronic. In the acute forms, there is great redness and injection of the affected membrane, swelling of the eyelids, and great secretion of tears, intolerance of light, pain in the eye, with the sensation of sand in it, and symptomatic fever. This latter is absent in the chronic form,

and in such the other symptoms are far less urgent. In treating inflammation of the conjunctiva, it is, above all, necessary to protect the eye from all sources of irritation. This is best done by darkening the room, and keeping the eye constantly covered with linen cloths, dipped in evaporating lotions, and changed from time to time, or with bread-and-milk poultices. If the fever be great, bleeding is proper; and in acute cases, the application of leeches in the neighbourhood of the inflamed organ is always advisable, and saline purgatives should be administered.

Nebula (see Plate II., fig. 4) is the name given to an effusion of lymph between the conjunctiva and the cornea, caused by inflammation. It produces, of course, more or less opacity. It is best treated by the application of opium, wine, or solution of nitrate of silver.

Pterigium is the name of a reddish preternatural membrane that sometimes begins to grow at the internal angle of the eye, and, gradually extending, at last obstructs the cornea. It is represented in Plate II., fig. 6. It is an occasional result of inflammation of the conjunctiva, and is most prevalent in warm climates: stimulating lotions may be applied to it, and these failing, it must be cut away.

The eyelids are liable to two or three somewhat peculiar affections. The most important of these are:—

1. The *Stye*, which is a small abscess that almost invariably goes on to suppuration. It is best treated by fomentations. When it has once come on in an individual, it is very liable to recur.

2. *Ectropium.*—This, as shown in Plate II., fig. 7, consists in a turning out of the eyelids, generally in consequence of the attacks of ophthalmia, or inflammation of the eye. It is a distressing affection, being generally accompanied by continual discharge of tears and inflammation of the conjunctiva, and sometimes by ulceration of the cornea. Application of lunar caustic to the inflamed edges is often beneficial. The appearance of the eye, when cured of this affection, is shown in fig. 8. The reverse of Ectropium is—

3. *Entropium*, or a turning in of the eyelids. The cure of this requires a surgical operation.

PRINCIPALS OF ALGEBRA.

CHAPTER VIII.

ALGEBRAICAL SYMBOLS.

72. We have hitherto regarded the symbols + and — as denoting simply addition and subtraction, and *zero* as the absolute *minimum* of all quantity. Thus far, therefore, our operations have been purely arithmetical; but we pass now to modifications in the meaning of our symbols, which have no direct parallel in arithmetic.

73. To express the difference of a and b, we write $a-b$. In an arithmetical sense, this difference is without meaning if b be greater than a, In this sense, we are therefore compelled to consider a and b as limited in relative magnitude, when placed in such circumstances with respect to each other; but as these symbols are general in their character, it becomes necessary to generalize the expression denoted by —, so that it may admit of application co-extensive with the symbolical quantities which it connects. Such an extension is deducible immediately from our rules: for,

1° Let a be *greater* than b by the quantity c; that is, let $a=b+c$ then $a-b=b-b+c$ which is $+c$.

2° Let a be *less* than b by the quantity c; that is, let $a=b-c$; then $a-b=b-b-c$ which is $-c$.

As these results, $+c$ and $-c$, are obtained by following established rules, they must admit of interpretations in conformity with the principles on which these rules are founded, The first consideration is this: + and —, when used to connect quantities which allow of combination, denote inverse operations; if, therefore, we would simply *extend* their meaning, so as to render them expressive of the qualities of isolated quantities, the properties assigned to them in this capacity must bear a similar relation.

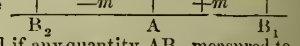
This relation is expressed when + prefixed to an insulated quantity is made to affect that quantity in a contrary way to — similarly prefixed; that is, when $+c$ and $-c$ are taken to express exactly opposite meanings of the same quantity c, as *profit* and *loss.*

74. *Definition.* When + and — are prefixed to insulated quantities, they are called signs of *relation* or *affection*; whereas, when they serve to combine quantities, they are called signs of *operation.* Moreover a quantity, whether combined or insulated, having the sign — prefixed, is said to be *negative,*

As there are but these two alternatives: either a quantity must be affected by the sign + or the sign —, it is agreed when no sign is used, to consider + as the sign affecting the quantity. c is therefore to be taken in the same sense as $+c$, and *vice versa.*

75. The following is then the meaning which we are to attach to algebraical quantities in relation to their signs: *They are either positive or negative according as they are affected by the sign + or — ; the signs + and — give to quantities directly opposite significations,* e. g. *if* +m *mean a gain of* £m, *then* —m *will mean a loss of the same amount ; if* +m *mean a loss of* £m, *then* —m *will mean a gain of the same ; if* +m *mean* m *years before, then* —m *will mean m years after ; if* +m *mean* m *degrees of south latitude, then* —m *will signify the same number of degrees of north latitude, and so on.*

The application of algebra to geometry immediately suggests this species of extension. If A be a point in a straight line, indefinitely extended both ways,



and if any quantity AB_1 measured towards the right of A be called $+m$, then the same distance AB_2 measured towards the left of A will be represented by $-m$. In the same way, the terms *height* and *depth, ascent* and *descent, above* and *below, backwards* and *forwards, before* and *after, heat* and *cold, property* and *debt,* involve in common the notion of opposite directions, and are consequently all symbolized by the signs + and — applied to the symbols denoting their magnitudes.

76. Addition and Subtraction. The first of these terms means the uniting of two expressions into one without altering the signs of either ; and the second, the uniting of two expressions into one by changing all the signs of that which is said to be subtracted. The following examples will show that these significations are consistent with the generalized meanings given to + and —.

Quantities given.	By the rule.	Admissible forms.		Results.
To a add $+b$	$a+(+b)$	$a+(0+b)$	$a+(b+0)$	$a+b$
To a add $-b$	$a+(-b)$	$a+(0-b)$	$a-(b-0)$	$a-b$
From a take $+b$	$a-(+b)$	$a-(0+b)$	$a-(b+0)$	$a-b$
From a take $-b$	$a-(-b)$	$a-(0-b)$	$a+(b-0)$	$a+b$

Let it be here carefully observed, that wherever two *like signs* come together in the operation, the corresponding part in the result has the sign +, and wherever two *unlike signs* come together, the corresponding part in the result has the sign —.

$\therefore a+(+b)$ may be written for $a-(-b)$ but the correct form is $a+b$

$\therefore a+(-b)$ . . $a-(+b)$. , . $a-b$

For Exercise. Show that the following equations are identical.

$$a+m-\Big(n-(m-n)+p\Big)=a+2m-2n-p$$

$$a-\Big\{a+(n-b+c)-2\Big(a-m-(n-b)\Big)\Big\}=2(a-m)+3(b-n)-c$$

$$1-\Big\{x-\Big(y-z-(x-1-(x-y))\Big)\Big\}=2-(x+z)$$

$$-m-\Big\{n-m\Big(n-p(q-1)-1\Big)-m-n\Big\}=m\Big(n-1+(1-q)\Big)$$

Let the effect of an *even* and an *odd* number of like signs be carefully observed in the following and similar formulæ.

$$-\Big\{-\Big(-(-x)\Big)\Big\}=+x \qquad +\Big\{+\Big(+(+x)\Big)\Big\}=+x$$

$$+\Big\{-\Big(-(-x)\Big)\Big\}=-x \qquad -\Big\{+\Big(+(+x)\Big)\Big\}=-x$$

$$+\Big\{+\Big(-(-x)\Big)\Big\}=+x \qquad -\Big\{-\Big(+(+x)\Big)\Big\}=+x$$

77. *Greater and Less.* These terms are symbolised by + and —, in their ordinary arithmetical signification of addition and subtraction ; but the extension of the meaning of our symbols requires a corresponding extension of the meaning of the terms which they are made to represent.